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[Place names have been transliterated from the German]

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The Geological Usefulness of Gravimet~~er~~ric Measurements in Germany and Croatia. Nature and Extent of Measurements in Croatia.

[Note: The term "isogam", used often here, may mean the "line of equal [fossil] plant growth".]

At the beginning of 1940, extensive gravimet~~er~~ric surveys of its petroleum concession areas were commenced by Petrolej, Inc. of Zagreb. It was not then clear to what extent such surveys would yield useful results for geology and particularly for petroleum exploration.

In 1933 the gravimeter had first been used for ~~ma~~Practrical work in Germany, and such use was limited to the Thyssen gravimeter. The initial use of such surveys was principally to study the regional gravitational correlations to supplement pendulum observations which had already been made. Thus gravimeter stations were spaced rather widely during this period. Although the results obtained were not without interest for general and theoretical geology, they did not, as a rule, yield enough information on the small-scale structures which are important for oil exploration. It should be recalled, in this connection, that even so large an elongated structure as that of Heide in Holstein, was not even detected by [redacted] the first gravimeter surveys, while its very close delineation subsequently became possible by means of seismic and torsion balance observations. On the other hand, closer spacing of gravity stations then located salt domes in Northern Germany, which were afterwards delineated precisely by the torsion balance. Salt domes, however, could hardly be looked for in Croatia; however, further surveys in the N piedmont of the Alps revealed that gravity values in that sector were primarily determined by the great and isostatically conditioned gravity deficit [anomaly] of the entire Alpine massif, so as to make local structures very indistinctly expressed in the gravity pattern.

Now, when we started modern, large-scale oil exploration work in Croatia, in 1939, we knew from the very beginning that we would have to use geophysical methods. Though some structures in Croatia, like the elongated and steeply upworked Triassic anticline of ~~Ivanscica~~ Ivanscica or the Triassic Cretaceous exposure of the Kalnik Mountains may be detected with sufficient precision by geological methods alone, they are not much use in oil exploration since such structures stand out too much in relief and are correspondingly eroded. On the other hand, it is hard to locate the potentially petroliferous structures in soft Tertiary layers by purely geological procedures, generally because of thick diluvial covering and limited exposures. Antidiluvian layers are not exposed at all on the extensive downstream depressions of the Mura, Drava and Sava which are covered with diluvial and alluvial depositions; nor are they any better exposed in the flatland between the Drava and Sava which are covered with diluvial and alluvial depositions; nor are they any better exposed in the flatland between the Drava and Sava rivers, east of Đakovo, except in the Fruska Gora mountains themselves. But it was just this area which seemed to offer considerable hope for

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the presence of petroliferous structures well compacted and at a greater depths.

It was therefore decided to have the entire exploration area of Petrolej, Ltd. covered as completely as possible by gravimetric surveys, in addition to the local torsion-balance and seismic work already done. The survey was made by two gravimeter parties of Seismos Ltd., of Hannover, under Engineer Partzsch and Dr. Schmidlin respectively, and one party of the Gesellschaft fur praktische Lagerstattenforschung [Mineral Exploration Company] of Berlin, under Engineer Graf. The stations were spaced, on the average, 1 to 2 kilometers apart. Special surveys in greater detail were also made in important areas i.e. at Medjumurje near Struzec, Martinska Ves and in the Gojlo area, and in such cases the stations were more closely spaced. 8,644 gravimeter stations in all were occupied.

The results were entered on 1: 75,000-topographic maps. On the two attached maps the scale has been reduced to 1: 200,000. In the discussions of the structures we have returned, as a rule, to the original scale of 1: 75,000.

The western boundary of the area surveyed runs along the Radkersburg-Varazdin-Zagreb-Lasinja line; the southern boundary is, usually, the Sava river, although a fairly large area in Bosnia south of the Sava river, was also covered in the Derventa-Gradacac-Brcko region; the eastern boundary runs along the Kuzmin-Vukovar-Erdut line; the northern boundary is the Drava river from its confluence with the Danube upstream to the confluence of the Mura river, whence to the Mura river is in turn the northern boundary, as far as Mursko Sredisce. The survey also included, north of the Mura river, the areas of Donja Lendava and Murska Sobota, which now belong to Hungary. A few unsurveyed gaps will be found within the territory so bounded. Such gaps are mostly over crystalline basement of no interest for oil exploration, as in the Moslavina, Psunj, Papuk and Krdnja Mountains. Some lesser gaps also remain, since the surveys had to be stopped in the fall of 1942, owing to increasing danger from partisans. These gaps are in the upper Lonja area between Krizevci and Komin; east of Bjelovar; between Grubisnopolje, Virovitics and Lisicine; the triangular Tertiary graben between the Prosara and Motajica Mountains, in the direction of Banjaluka in Bosnia; and the entire E part of the mineral claim between the Danube and the Sava river, from Kuzmin to Zemun. The clarity of the pattern as a whole is not essentially impaired.

~~[illegible]~~, It soon developed however that the gravity anomalies usually give a reliable idea of the general structural geology. The crystalline cores of the basement rock always stand out as strong gravity maxima, and the Tertiary graben as pronounced minima. It should be pointed out, however, that the densities of the Tertiary rocks in this area have not yet been determined. But is is certain that they are consistently much lighter than the crystalline massifs of granite, gneisses, amphibolite, schists, etc. Also the mesozoic anticlines which plunge into the deep Tertiary basins, such as the eastern continuation of the Ivančica and Kalnik Mountains, appear as pronounced maxima in the gravity pattern. Even the buried ridge of Selnica-Peklenice, in the core of which no Pre-Tertiary rocks have ever been found, still registered a strong gravity maximum. On the other hand, other anticlines, folded in the late Tertiary, such as the Gojlo dome and the Resetari buried ridges, showed only slight gravity-relief, owing to the structural geology of the deeper strata. These examples are enough to make it quite clear that although the gravity maps can give us an important general view of the structural geology, it is possible to attain a more precise understanding only by comparing the geological conditions in detail with the gravimeter data. This will be done below, and the gravity conditions considered in detail with the aid of the annual 133 gravity profiles.

Geophysical and geological description of the individual structures.

The entire territory is divided by two graben or geosynclines striking from W[redacted] to E[redacted]. The Drava and the upper Lonja follow the course of one of these geosynclines while the lower Sava river follows the other. The area North of the Drava geosyncline will first be discussed, then the Drava geosyncline itself, the mountainous and hilly country between the Drava and the Sava geosynclines, then the Lonja Sava geosyncline, and finally the structures W[redacted] and S[redacted] of the Lonja Sava geosyncline. A more detailed geological arrangement of the mesozoic anticlines which plunge into the deep Tertiary basins, such as the eastern continuation of the Ivančica and Kalnik Mountains, appear as pronounced maxima in the gravity pattern. Even the buried ridge of Selnica-Peklenice, in the core of which no Pre-Tertiary rocks have ever been found, still registered a strong gravity maximum. On the other hand, other anticlines, folded in the late Tertiary, such as the Gojlo dome and the Resetari buried ridges, showed only slight gravity-relief, owing to the structural geology of the deeper strata. These examples are enough to make it quite clear that although the gravity maps can give us an important general view of the structural geology, it is possible to attain a more precise understanding only by comparing the geological conditions in detail with the gravimeter data. This will be done below, and the gravity conditions considered in detail with the aid of the annual 133 gravity profiles.

Geophysical and geological description of the individual structures.

The entire territory is divided by two graben or geosynclines striking from W[redacted] to E[redacted]. The Drava and the upper Lonja follow the course of one of these geosynclines while the lower Sava river follows the other. The area North of the Drava geosyncline will first be discussed, then the Drava geosyncline itself, the mountainous and hilly country between the Drava and the Sava geosynclines, then the Lonja Sava geosyncline, and finally the structures W[redacted] and S[redacted] of the Lonja Sava geosyncline. A more detailed geological arrangement of the

I. THE TERRITORY N[redacted] OF THE DRAVA GEOSYNCLINE

The surveyed territory lying north of the Drava river is the geological border between the Sava river-folds and the Graz embayment. The Sava river folds represent the eastern spurs of the Alps, which have been sharply folded upwards as recently as in Pliocene times: the Graz embayment is an intrusive basin along the east margin of the crystalline Central Alps, in which the Tertiary layers have been dissected by faults in some places and broken through by basalts and andesites. The anticline of Selnica has hitherto been considered the northernmost of the Sava river folds, this anticline diverges from the Voc Mountains near Fridau, crosses the Drava river, and then runs from Selnica via Peklenica to Lispe in Hungary. The gravimeter surveys of Petrolej, Ltd, then located another high but farther to the northwest, in the environs of Murska Subota - - which gravimetrically resembles that of Selnica. A gravity depression was located near Radkersburg itself. Thus we have the following structures from northwest to southeast:

a. The Radkersburg syncline

b. the high of Murska Subota [Murasszombat in Hungarian] - Bagonya;

c. the syncline of Luttenberg; and

d. the buried ridge of Selnica-Peklenica-Lispe

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(A) The syncline of Radkersburg (See profile 1).

A gravity-trough striking SW [redacted] to NE [redacted] passes through Radkersburg itself. Its lowest value is + 0.5 mgal, about 8 kilometers NE [redacted] of Radkersburg. A sharp rise NW [redacted] then carries the gravity up to + 25 mgal. There can be no doubt that this rise is due to a sill of Lower Paleozoic schists in the NW [redacted]; this sill even outcrops to the surface near the former junction of the former frontiers of Austria, Hungary and Yogoslavia as the Roter Stadelberg massif, 7 by 3 kilometers in size. The highest gravity value, + 25.1 mgals is still about 4.5 kilometers from the E [redacted] margin of the outcropping schist.

Argillaceous marls rich in fossils and Sarmatian sands outcrop near Radkersburg. This entirely corresponds to the usual structure in the Vienna basin. Combustible gases of unexplained origin showed in the immediate vicinity of Radkersburg, and on the strength of this, an exploration well 400 meters deep was drilled there in the year 1927. This yielded the following profile:

0 - 24 meters	24 meters	Diluvium
24 - 220 meters	196 meters	Middle Sarmatian formations
220 - 400 meters	180 meters	Lower Sarmatian formations

The Sarmatian formations consisted of alternating beds of gray argillaceous marls and loose sands. There was an abundant deposit of typical fossilia in the Sarmatian formations, especially of Cerithians. The Sarmatian argillaceous marls were somewhat bituminous in places; and thin crack fillings of asphaltic substances were also found. No oil or combustible gases showed, but on the other hand, water and carbonic acid gas were encountered at the lower levels. In any case, the latter find is correlated with the final manifestation of Tertiary vulcanism in SE [redacted] Styria. At the final depth of 400 meters the bottom edge of the Sarmatian had presumably been fairly well reached. In any event, the Sarmatian-formation near Radkersburg is at least 475 meters thick, and this great thickness strongly contrasts with the usual thickness of the Sarmatian layers in Croatia - - about 50 meters. Similarly, the whole facies contrasts with the development of bituminous shale which is so characteristic for the Sarmatian in most of Croatia. Only this unusual thickness of the Sarmatian explains the presence of a gravity trough near Radkersburg, in spite of the outcroppings of Sarmatian, while even formations occur on the surface, on the buried ridges of Selnice and Lispe Sarmatian is met only at great depths. But this gravity-trough presumably justifies the conclusion that the thickness of Mediterranean II is also not entirely inconsiderable in the Radkersburg basement. Moreover, even the lowest gravity of the minimum near Radkersburg - - + 0.5 mgal, - - is still considerably higher than the lowest gravity in the next minima to the east: Luttenberg (- 8.2 mgal.) and Cacovec (- 5 mgal.) See profiles 1 and 2.

(B) The high of Murska Soboto - Bagonya (See profile 1.)

The gravity-high of Murska Sobota was geologically a complete surprise, for the topography fails to reflect its existence, since for the most part it lies in the depression of the Muna river, and the hilly country south of the Mura river also failed to reveal its presence in the topography of the brooks and upland ridges, the trend of which, rather, at right angles to the structure. It seemed necessarily to the oil geologist that the Murska Sobota structure was worth looking into for the gravity pattern resembles that of the petroliferor structure of Selnice-Lispe, only 25 kilometers away, directly across the Luttenberg syncline. On the other hand, the position, on the NW [redacted] flank, of the Radein springs, strongly changed with CO_2 and resulting from the final manifestations of Tertiary vulcanism, gave rise to serious doubts from the very beginning. The highest gravity in the maximum was + 10.3 mgal, 3.5 kilometer W of Murska Sobota; + 9.9 mgal were again encountered in the area A of the Mura river. E of the high of Murska Sobota there is only the gravity-spur of Bogonya, (+ 4.3 mgal). Magnetic surveys of the area were also made, to establish, if possible, whether there was any connection between the gravitational anomalies and late volcanic intrusive masses. A fairly large positive anomaly in the vertical component of the earth's magnetic field was found; it amounted to about 200 γ , was found, and similarly trended from SW to NE. Its magnetic axis almost coincides in the N with the gravity high of Bagonya; but in the S it passes about 4 kilometers to the E of the S portion of the gravity high of Murska Sobota. The area of magnetic disturbance is probably due to the superposition of strongly magnetic basement formations, which coincide only partially with the gravimetrically effective masses and presumably also lie at lower levels.

Deep drilling has also been undertaken recently at the high of Murska Sobota. According to the meager report submitted, this drilling is said to have reached a depth of almost 800 meters through Pannonian layers, encountering the crystalline basement at a depth of 800 meter. The slight thickness of the Sarmatian, or its complete absence, as well as the unusually shallow position of the basement rock, are both surprising. Confirmation of both phenomena would indicate that the Murska Sobota-Bagonya structures had formed an important sill in Sarmatian times, separating the thick Styrian formations of this stage rich in fossils, from the thin bituminous Croatian formation. With respect to the depth of the basement, it should be remembered that well R 19 on Raky Hill near Selnica, with +18 mgal at the surface went down to 1083 meters without reaching the bottom of the Tertiary, while the well recently drilled at + 10.3 mgal near Murska Sobota encountered crystalline as early as at only 800 meters depth. This can probably be explained by the expecially low density of the Pannonian at Murska Sobota, which often consist of loose sands and gravel, as compared with the heavier Valenciennesian marlsand the compact Mediterranean sandstones of Selnica.

In conclusion, it may be remarked that although a gravity-spur like that of Bagonya, might well seem not very promising as an oil structure because of its somewhat uncertain round shape, the oil fields of Peteshá́za and Lovászi are nevertheless also located on a gravity spur, similar to that of the buried ridge of Selnica.

(C) The Luttenberg syncline (Profiles 1 and 2).

Geological surveys of the Mura Island had already shown that the Luttenberg syncline trending SW to NE, lies W of the buried ridge of Solnica. The gravimeter surveys confirm the existence of this syncline. They revealed that the syncline must lie at a very great depth, since the gravity values sink to - 8.2 mgal. Such low values are met only in the deepest graben in Croatia: the Čakovec syncline with (--5 Ngal), the Drava syncline near Vaska (-4 mgal), near Moslavina (- 6 mgal), the syncline of the upper Lonja, (0 mgal), the Sava syncline near Nova Gradiska (- 13.6 mgal). The deepest point of the Luttenberg syncline lies on the Mura river itself, about 5 kilometers from Luttenberg.

(D) The buried ridge of Selnice-Lispe (Profiles 2, 3, and 4).

Engineer Graf made gravimeter survey of the central portion of this important petroliferous structure was first

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detected during a reconnaissance gravity survey of its Central part, made by Engineer Graf. Subsequently Dr. Bitter's party occupied more than 600 torsion-balance stations in the Selnica-Pahlenica-Donja Lendava area, but we shall not go into the details at this place. Finally, the Mursko-Sredisće-Dolnja Lendava area on the former Hungarian-Yugoslav frontier, was surveyed more in detail by Engineer Partzack's party, occupying closely spaced gravimeter stations.

The structure of Selnica revealed itself as a large and very pronounced maximum, with axis striking W to E and plunging toward the E. Thus it will be seen that the entire gravity pattern is in complete agreement with the structural geology. This could not be assumed a priori, without qualification, for the buried ridge gives little topographic indications of its existence, and, as far as could be learned by deep drilling, it is entirely composed of folded late Tertiary sediments, which could not be assumed to exercise so very considerable a gravitational influence. The highest gravity near the axis at the drilling site of Selnica was about +18 mgal, while the isogams drawn from torsion balance data gave + 20 mgal on the axis, and about + 22 mgal in the Selnica valley, 1 kilometer to the W. (profile 4). Corresponding to the fall in the anticlinal axis, the gravity at the Mur II well to the E, is + 18.7 mgal; at Peklenica the axis is cut by the + 15 mgal. isogam and the gravity of the axis has sunk to + 12 mgal at the former Yugoslav-Hungarian border

In contrast, the values along the flanks of the ridge (Profile 2) toward the Luttenberg syncline on the N sink to -8.2 mgal and toward the syncline of Čakovec on the S to -5 mgal. This results in the following gravity increases:

	Minimum at Syncline	Maximum at Selnica	Difference	Distance	Gravitational Gradient
Syncline of Luttenberg	-8.2 mgal	+ 22 mgal	30.8 mgal	14 km	2.2 mgal/km
Syncline of Cakovec	- 5 mgal	+22 mgal	27 mgal	12 km	2.3 mgal/km

In some places along the flanks of the structure the fall in gravity is still more considerable. Thus, according to the torsion-balance traverse along the S flanks somewhat south of the axial region, the gravity drop from + 18 to + 14 mgal in 800 meters corresponding to a gravitational gradient of 5 mgal/km.

For comparison, a few other striking gravity differences in structures located in Croatia and elsewhere are presented:

	Maximum mgal	Minimum mgal	Difference mgal	Distance in Km	Gradient mgal/km
Lispe, S flank	+17	+3.3	13.7		
Murska-Sobota: SE flank	+12	-6	18	12	1.5
Ludbreg N flank, total	+23	-4	27	16	1.7
Ludbreg N flank, steep zone	+19	+5	14	4	3.5
Sedlarica N flank	+27.1	+3	24.1	8	3.0
Lisičine N flank	+48	-4	52	20	2.6
Križ-Šumečani: SW flank	+14.3	+4.2	10.1	6	1.7
Mikleuška SW flank	+31	+9	22	7	3.1
Goilo SW flank	+18.3	+3	15.3	5	3.1
Psunj Mtns-Nova Gradiška	+38.6	-13	51.6	15	3.4
Psunj Mtns,-Sagovina-Bogićevci	+28	-13.6	41.6	7.5	5.5

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Zistersdorf near Vienna, Steinberg fault	+1.5	-18	19.5	6.5	3.0
Oberlass, S of the Vienna basin	+30	+2	28	8.8	3.2
Heidelberg marginal fault of the Rhine valley graben	+18	-26	44	9	4.9

Thus it will be seen that the gravity difference of about 30mgal between the maximum and minimum at Selnica is very high compared to the other Hungarian-Croatian structures. Higher gravity differences have been found only where the maximum is above heavy crystalline basement -- at Mikleuška, the Paunj Mountains, Lisičine N in addition we must bear in mind that in almost all these structures such great differences occur only on one side of the structure. Only in the structures of Lispe and Murska Sobota, of all the foregoing, have any symmetry at all, with deep minima along both flanks. At Lispe, which, of course, is part of the same structure as Selnica, the differences in the direction of Papp have dropped as low as 13.7 mgal in the S and 7 mgal in the N. While at Murska Sobota the differences along the SE flank are as high as 18 mgal, along the NW flank they are only 9 mgal. The structure of

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Selnica is, therefore, gravimetrically the most marked in the entire survey area.

The gravitational gradient between maximum and minimum at Selnica ranges from 2.2 to 2.3 mgal/km and is about midway in the table above presented. We have to bear again in mind in this connection that in the other structures as a rule the high gravitational gradients occur only on one flank and that crystalline outcropping also increase gravitational gradients. In any event, the gradient of 5 mgal/km, on the slope of the S flank of the buried ridge at Selnica is very high. Comparable gradients have been found only along the S slope of the crystalline Psunj Mountains, toward the deep geosyncline of Bogičevci.

To aid in the geological interpretation of gravity observations, we present the summarized profiles of the drillings known as Raky 19, Mura I and Peklenica 47, in the axial region of the Selnica buried ridge; in this connection the data relating to Raky 19 have been reconverted in accordance with more recent experiences gained in the deeper portions of the same:

Raky 19 (+ 21 mgal)

0 - 14 meters	14 meters	loam and gravel	Diluvium
14 - 133 meters	119 meters	argillaceous marls with thin sand layers	Middle Valencien-nesia layer
133 -388 meters	255 meters	firm argilla-ceous marls	Lower Valencien-nesia layer
388 -610 meters	222 meters	bituminous shales, argillaceous marls, thin sandstone strata	Sarmatian
610-1083 meters	473 meters	dense calcareous sandstones, finely conglomerate Litho-thamnium sandstones, argillaceous marls	Mediterranean II.

Mura I (+ 18.5 mgal)

0 - 18 meters	18 meters	loam and gravel	Diluvium
18 - 130 meters	112 meters	grayish-bron priable sandy marl	Rhomboidal layers
130-408 meters	278 meters	alternating argillaceous marls and sand	Upper Valen-ciannesian layers
408-612 meters	204 meters	gray, firm argilla-ceous marls	Lower layers

612 - 834 meters	222 meters	gray argillaceous priable marls with sandstone strata	Pro-layers
834 - 900 meters	66+x m	bituminous marlaceous shales, argillaceous marls, micaceous psammite sandstone	Sarmatian

Peklenica 47 (+14.8 mgal)

0 - 20 ±	20 m		Diluvium
20± 580 ±	560 m	grayish-brownish, sandy marls with sand deposits	Rhomboidal layers
580± 840 meters	260 m	sands and argillaceous marls alternating	upper Valenciennesian layers
840 - 1008 meters	168 m	gray, solid argillaceous marls with sandstone deposits	Pro-layers

Therefore the 500 m difference in level between the upper edges of the Sarmatian between Raky 19 and Mura I corresponds to a 2.5 mgal difference in gravity at the respective well-tops; and a 400 meter difference between the edges of the of the Pro-Valenciennesian between Mura I and Peklenica 47 corresponds to a 4.3 mgal difference in gravity, and the total difference in the level of the respective beds fron one end of the anticlinal axis to the other - - about 900 meters -- corresponds to a gravity difference of about 7 mgals.

From these figures, the base of the Pliocene in the deepest synclines N and S of the Sava might be assumed to be at a depth of about 3,600 meters. Though there is no data in direct support of this hypothesis, it would not conflict with the known minimum thickness of about 1600 meters for the Philocene in the oil fields of Lovassi and Lispe in Hungary, which are also located on high-gravity structures.

It is now proposed to discuss the problem of the strong gravimetric total effect of the structure of Selnica and the high gravitational gradient of its flanks. In any case, the great thickness of the Upper Pannonian sediments, the probable effect of which has just been pointed out, is important part in this connection in the adjacent synclines, as is also the density of the Tertiary stages, which increases with depth. The friable, sandy Rhomboidal layers are in any case the lightest sediments. The denser marls of the Valenciannesian layers are heavier; Mediterranean II, frequently composed of compact calcareous sandstones and finely pebbled conglomerate lithothamnium sandstones, is still heavier. But this does not still fully explain the intense gravitational influence of the Selnica buried ridge, which suggests a core of even compact rocks. According to the analogy with the Ivančica and Voč Mountains, from which latter mountains the anticline of Fridau-Selnica branches off S of the Drava river, we are well justified in assuming the presence of a core of Triassic limestones and dolomites within the inner portions of the Selnica structure. It is quite probable that if the well Raky 19 were continued down for a few hundred meters more, it would penetrate into this core at a depth of about 1500 meters.

Judging from the powerful gradients of the flanks, we may furthermore assume that this Triassic core has been upward in a steep, probably in a somewhat perforated manner, similar to that of outcropping strata in the Ivančica Mountains. This assumption has been substantiated by the fairly steep angle of the dip (the northern flank up to 55 degrees, the southern flank up to 35 degrees) found during the mapping of the Selnica area, but in the first place through the steep angle of the dip (40 degrees to 56 degrees) in the lower parts of the Raky 3, 17 and 19 wells.

We shall now discuss the gravimetric conditions of the Dolnja Lendava-Lovaszi areas which are all the more important since the petroliferous Lovászi area also embraces sections of formerly Yugoslav territory. Although the data of the surveys originally made in Hungarian territory are not available in the environs of Dolnja Lendava will be quite sufficient to understand the essential features involved. The latter surveys show that, the Dolnja Lendava-Lovászi area constitute a gravity-terrace projecting NE towards Lovászi

Kutfej from a gravity-level half-way up the N flank of the Selnica-Lispe maximum (Profile 3). This is chiefly manifested in the shallowing between isogams +10 and + 11 mgal and between + 9 and + 10 mgal. While for instance the strips between the isogams of +13 and +14 mgal + 13 and +12 mgal, and +12 and +11 mgal have a width of about 500 each, the strip between the isogams of +11 and +10 mgal near Petesháza are as wide as 1500 meters, while between isogams + 9 and +10 mgal, near Völgyifalu, the width of the strip even reaches 300 meters north of isogam +9 mgal a normal gravitational gradient of about 2 mgal per kilometer again follows. There are still some small convexities, less than 1 mgal in amplitude, along the wide gravity-terraces between isogams +9 and +11 mgal. Oil was struck on one of them at Petesháza, while deep drilling, on the Manat, near Volgyifalu, is now under way on another. The terraces and small lateral axes striking N are plainly recognizable on the annexed 1: 200,00 map and on profile 3. It is a point of general importance that the oil deposits in these areas are not confined to the axes of the gravity maxima but may also be met along the terrace-like gravity structures on the flanks of the maxima.

II. THE DRAVA GEOSYNCLINE

The deep and elongated minimum of the Drava geosyncline or graben, is divided into two sections, one running W and E from the Cakovec to Prelog depression and the other running from NW to SE along the Legrád-Vaška-Moslavina-St.

Djuraj line.

(A) The Cakovec-Prelog section.

This deep minimum strikes W to E between the Ivancica Mountains in the S, which are highly upworked, and the anticline of Selnica in the N. The axis of the minimum passes through the Drava river some 5 kilometers to the N. Here we have the especially deep gravitary troughs of Čakovec (- 5 mgal) and Prelog (-4 mgal). We have already stated that the bottom of the Pliocene may be assumed to lie at the depth of about 3,000 meters in this depression. In this case the bottom of the Tertiary should then be assumed to lie at a depth of about 4,000 meters; this also agrees with an overlapping gravimetric calculation made by Engineer Graf.

The isogams of the boundary of the S veer to the ENE, E of Prelog. This is due to the anticlines of the Ivančica and Kalknik Mountains, which follow to the S they plunge towards the E and merge into one gravitational mass N of Koprivnica, and gradually continuing to submerge, they proceed in the ENE direction toward Légrád. This axial zone projecting E forces the connecting link graben and the next section on the N to penetrate onto Hungarian territory beyond the river. In consequence, the S flank of the graben, which is very steep from the W to a point about 3 kilometers E of Ludbreg, now becomes considerably flattened in its further eastern course.

(B) The Légrád-Vaška Moslavina-Sv. Gjuraj section.

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In this section the axis of the minimum runs from NW to SE for about 120 kilometers, mostly close to the Drava river and the Hungarian border. Here we have a wide and fairly deep geosyncline. We find the lowest values at Vaška (-3 mgal) and at Moslavina on the Drava river (- 6.2 mgal). The SW edge of the geosyncline first climbs with moderate steepness to Pitonača-Sedlarica, and the Bilo Mountains; thence the ascent to the Papuk Mountains is very great and steep. In the table on page 25, of conspicuous gravitaty differences, belong the N flanks of the Sdlarica Lesičine structures with respective differences of 24.1 mgals and 52 mgals, and respective gravitational gradients of 3 mgal/km and 6.2 mgal/km. No positive gravitational axis worthy of mention cuts through the entire Legrad Sv. Gjuraj section of the Drava geosyncline. The mild uplifts between the lowest depressions at Vaška and Moslavina cannot be considered an axis in the proper sense of the word. As a result, the previously assumed correlation of the range of Görgeteg in Hungary with the Bilo structures in Croatia cannot exist.

The syncline of the Drava river rises from the depth in the E like the bow of a ship in the Sv Gjuraj area on the Drava river, between the high N of Miholjac Dolnji and the lower level high of Črnkovci, with + 6 mgal at the Drava river. Here the syncline of the Drava river passes over to Hungarian territory where it can hardly still be of any importance, however, since the strongly Mesozoic formation of the Vilanj Mountains passes as close as 10 kilometers N of Miholjac Dolnji. In any event, no

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minimum zone follows the last sector of the course of the Drava river from Sv. Gjuraj till its confluence with the Danube; it rather crosses several maxima, to be discussed below, between which pass lesser, not deeply embedded minima of no great depth.

III. THE MOUNTAINOUS AND HILLY COUNTRY BETWEEN THE DEPRESSION OF THE DRAVA AND SAVA GEOSYNCLINES

This is the central section of the petrolej oil concession. Here lies the crystalline cores of the Moslavina and Psunj Mountains. Many details with respect to the geology of the Tertiary in the marginal zones of these mountains have become known; here we find a series of oil and gas outcrops which have been known from times immemorial, and finally here is the oilfield of Gojlo. In agreement with the foregoing, the gravimetric results can be evaluated geologically from many aspects. However, all the older formations disappear under the plain covered by diluvial deposits E of the NS line of Našice-Brod. Here the gravimetric studies prove to be all the more valuable; however, they can be interpreted only subject to reservations until exploratory wells are sunk.

<u>(A) The W portion of the mountainous and hilly country between the Drava and Sava rivers geosynclines as far as the Nasice-Brod line.</u>

The plunging axes of the eastern, so-called Sava

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river fold lie south of the western section of the Drava geosyncline, namely those of the Ivančica and Kalnik Mountains. They are the following:

(a) The Ludbreg axis,

(b) the axis of Veliki Poganec -Subotica,

(c) the Lepavina axis

These three axes belong to a larger unified gravity axis between the Drava graben in the N and the graben of Križevci and Bjelovar. The axis of Ludbreg represents the plunging anticline of Ivančica, while the axes of Veliki Poganec and Lepavina split off from the subsiding Kalnik mountains.

(a) The axis of Ludbreg

The longest and most discernible fold of the Sava river is that of the Ivančica Mountains, culminating in the Triassic eminence 1600 meters high, to the SW of Varaždin. This anticline consistently strikes W and E. In plunging towards the E the Triassic is first covered by Leitha limestone south of Varaždin and this limestone then dips beneath Sarmatian and Pannonian formations near Varazdinske Toplice. From there to the region of Ludbreg-Belfen, for 17 kilometers the anticline lies entirely in Pannonian: the Valenciennesian layers outcrop in the W portion of this sector and the Rhomboideal layers do so in the E portion.

The gravimeter surveys in the valley of the Bednja revealed that the anticlinal zones of the Ivančica and Kalnik

Mountains merge into a wide gravitaty high west of Slanje. This high has been traced in the upward direction till the outcropping Oligocene of the northern flank of the Kalnik Mountains near Drenovec, where the Triassic basement does not lie very deep in any case, and where + 31 mgals have been noted. (See sheet 1 of 1: 200,000 map)

The Ludbreg high proper then branches off somewhat to the W of trigonometric point 291 near Segovine [See profiles 5 and 6]. The gravity is 21.5 mgal at point 291, where the Valenciennesian layers crop out to the surface. The maximum axis continues its trend, reaching the Drava plain (+ 20 mgal) at the Ludbreg I well, between Čakovec and Bolfan. The Ludbreg I well has the following summarized profile:

0 - 32.5 m	32.5 m	loam, sand and gravel	Diluvium
32.5 - 356 m	323.5 m	grayish-brownish, sandy marl	Rhomboideal layers
356 - 748 m	392 m	gray, firm argillaceous marls, sand deposits at the bottom	Upper Valenciennesian layers
748 - 1100 m	352 m	solid argillaceous marl and splintery marl	Lower layers
1100-1336 m	236 + x m	Alternating splintery marly limestones with friable sandstones	Pro-layers

The Triassic basement may be assumed to lie underneath the drilling at a depth of about 1700 meters.

Subsequently the high of Ludbreg has been traced toward the E onto the plain, especially by torsion-balance surveys. Then about 7 kilometers E of Ludbreg I deep well, with the high of Veliki Poganec-Subotica merges with this high and small anomalies again occur, only at a point 5 kilometers S of Legrád in the + 13 and + 12 isogams, which are probably correlated with the axis of Ludbreg. Mention should be made of the fact that gravimetrically the region of Légrád still is sufficiently high above the Drava geosyncline as to make the occurrence of oil at least possible.

The gravimetric high at the dome near bench mark No 291 Segovina is fairly wide. The drop from here to the intermediate syncline of Rijoka Duga is slight; it amounts only to about 3 mgal in 3 kilometers, corresponding to a gravitational gradient of 1 mgal/km (See Profile 5). A similar mild gravitational gradient also rules along the N flank till the region of the drilling along the Bednja is reached. Here the gravity falls from + 21.5 to + 19 mgal in 3 kilometers, corresponding to a gravitational gradient of 0.8 mgal/km. From the Bednja, the gravity sinks toward the N till the drilling of Ludbreg II is reached in 1400 meters, from + 19 mgals to +15.5 mgals, corresponding to the strong gravitational gradient of 2.5/km.

The profiles of the wells along the Bednja, and that of Ludbreg II, with the deeper bracketed portions of the profiles juxtaposed, are as follows:

		Bednja III at 19 ngal deeper than 514 m combined (1)	Ludbreg II at 15.5 ngal deeper than 1500 m combined (2)
Diluvium	Loam, Sand and gravel	0 - 35 m 35 m	0 - 30 m 30
Rhomboideal layers	grayish-brown fine-sandy marl	35 - 105 m 70 m	30 - 496 m 466
Upper Valenciennesian layers	gray solid argillaceous marls	105 - 514 m 409 m	496 - 931 m 435
Middle Layers"	solid argillaceous marls with separate sandstone schlieres	514/ab. 675 m/ 161 m	931 - 1150 m 219
Lower layers"	argillaceous marls and splintery marls	675 - ab.800 m 125 m	1150 - 1324 m 174
Pro-Layers "	marls and porous sandstones	/500 -ab.1100 m 300 m/	1324 -/ab. 1600 m 276
Sarmatian formations	bituminous marlaceous shale	/1100 - ab. 1200 100 m/	/1600 -ab. 1700 100

		(1)	(2)
Tortonian	marlaceous sandstones and Leitha limestone	/1200 - ab. 1500 300 m/	/1700 - ab 2000 300/
Triassic		at about 1500 m	at about 200 m

Accordingly the layers sink by 400 500 meters in the 1400 meters between Bednja III and Ludbreg II, and the gravity sink correspondingly from +19 mgal, to +15.5 mgal, or 3.5 mgals. Entirely corresponding decreasing gravity values along pitching layers have been found in the axial region of the Selnica buried ridge. [See page 28]. From this Ludbreg data, the bottom of the Pliocene in the syncline of Prelog, which adjoins on the N would lie at a depth of almost 4100 m, while calculations from the Selnica data give 3600 meters.

In agreement with the steep gravitational gradients in the drilling Ludbreg II, especially in the middle depths of about 1000 meters, a steep flexure-like dip running as high as 50 degrees was formed in the layers.

It would appear that the steep dip of the layers still continues N of the drilling for about 3 kilometers, since the gravity values continue to sink very sharply till the value of + 5 mgals is reached (Profile 5). This corresponds to the high gravitational gradient of 3.5 mgals/km. This drop is one of the most pronounced ones ever found in the survey area in Croatia, as will be seen by consulting the Table on page 25. This table reveals that the total gravity drop of 27 mgal, along the northern flank of the Ludbreg structure, is very strong and that it is stronger only in ranges where the maxima lie immediately on crystalline basement. The gravitational gradient of 3.5 mgal/km in the steep zone of the Ludbreg structure is likewise strong, compariable values being met elsewhere only where there are powerful fault disruptions or steep flexures. It is a remarkable fact that the gravitational gradients of 3 or 3.18 mgal/km, respectively, along the extensive quarry fault in the Vienna basin is quite similar. Although the drilling at Ludbreg II did not reveal any oil accumulation within the range of this flexure in the valenciennesian portions and in other portions surveyed, this does not mean that there could be no oil accumulation in other places of this flexure. In addition, the isogems branch off east of Ludbreg, with the result that the flexure is here apparently flattening out again.

Another problem arising in connection with the Ludbreg area involves the relation between depth of the Tertiary basement and gravity anomalies. The following table summarizes the data on gravitational anomalies and the depth of the Tertiary basement as shown by recent drillings:

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	Gravitational anomaly	Depth of the basement
Sedlarica	+ 27.1 mgal	deeper than 860 m
Veliki Poganec	+ 26 mgal	about 400 m
Grubisnopolje	+ 25.4 mgal	1029 m
Ludbreg I	+ 19.7 mgal	deeper than 1350 m about 1700 m
Ludbreg II	+ 16.5 mgal	deeper than 1500 m, about 1800 m
Selnica Raky 19	+21. mgal	deeper than 1100 m, about 1500 m
Selnica Mura I	18.5 mgal	deeper than 900 m, about 2000 m
Selnica, Peklenica 47	14.2 mgal	deeper than 1030 m, about 2200 m
Kravarsko	16.3 mgal	less deep than 1000 m
Gojlo	18 mgal	2156 m
Bujavica	14.5 mgal	1331 m
Janjalipa	13.2 mgal	about 1800 m
Petesháza	10.5 mgal	deeper than 1740 m, about 2500 m
Sicak	9.8 mgal	deeper than 1015 m, about 2000 m
Osekovo	9.65 mgal	deeper than 1720 m, about 2800 m
Rosetari	2.9 mgal	about 2600 m

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It follows from the foregoing survey that the depth of the Mesozoic or crystalline basement of the Tertiary, very roughly, varies inversely with the gravitational anomaly. A strict correlation is not present, however. There must be still other factors which are decisive for the extent of the anomalies, as for instance the density of the rocks of the subjacent basement, the density and the thickness of the separate Tertiary stages and probably also the regional gravity gradients. Otherwise we could not have formed + 14.5 mgal, at Bujavica, where granite is met at the depth of 1331 meters, while at nearby Gojlo the higher value of + 18 mgal, was found, in spite of the considerable greater depth of the basement at 2156 m.

(B) The Veliki-Poganec - Subotica axis. (See Profiles 7, 8 and 9.)

The Veliki Poganec-Subotica buried ridge or saddle forms an integral part of the Kalnik anticline, plunging toward ENE, as will be shown by a glance at Sheet 1 of the 1: 200, 000 map. The Rasinja syncline separates this saddle, on the N from the Ludbreg saddle, while on the S the Koprivnica syncline separates it from the Lepavine structure (see Profiles 7 and 8.) Gravimetrically the Subotica saddle is smaller and more sharply defined than the Ludbreg high. From Apatovac, where a Leithe limestone transpression on older basement rock drops out to the surface, the saddle axis first runs west and east to Veliki Poganec. A short distance east of Veliki Poganec it appears to undergo a slight interruption, shown for the time being by gravity observations.

In the Prkos it becomes distinct once again and runs over the high Pesek to Subotica, whence it leaves the hill-country for the plain, where it has been observed in detail by torsion balance observations, finally dying out about 6 kilometers east-northeast of Subotica.

On the outcropping Leithe limestone near Apatovic, the gravity at first is .32 mgal, and then sinks to .25 mgal between here and Veliki Poganec, where Mediterranean II lies at a depth of about 220 meters. Thence it falls slowly to reach 20 mgal at the deep well Subotica I and finally reaches + 13 mgal towards the end of the anticline, where it dies away. (See Profile 9). The Subotica I well which is located on the same + 20 mega-isogam as the Ludbreg I well, also encountered an entirely similar profile during drilling, with the single difference that in the former case the boundary between the Valenciennes and Pro-valenciennes layers occurs at a depth of 1250 meters, or 150 meters deeper than in Ludbreg I.

On the whole, the gravity drops constantly towards the east along the anticlinal axis, as do, stratigraphically, the Tertiary members. Only at the High Pesek, about 1 kilometer west of the Subotica I bore hole, is a small local dome of about 0.5 mgal amplitude superimposed upon the gravity axis, and there is also presumably a second similar local dome near Prkos. In the light of the many oil showings revealed by the counterflush drilling of Petrolej, Inc. at the upstriking western end of the saddle near Ribnjak and near Veliki Poganec, further exploratory drilling on one of these two domes would appear to be in order.

(C) Lepavina axis (See Profiles 10, 11 and 12).

This structure splits off from the southwest corner of the Kalnik anticline. With the exception of the Marinovac bore hole, drilled by the British, which is west of the structure proper, no drilling has yet been done on this saddle formation. The Lepavina structure is gravimetrically distinguished by the fact that the + 28, + 27 and + 26 mgal-isogams all lie compact and closed around the + 28.8 mgal gravity maximum. Closed, compact maxima favorable for oil prospects are by no means frequent throughout the entire exploration area of Croatia. The marked drop in gravity on the south flank, as far as the Krizevci and Bjelovar synclines, is also favorable; this amounts to a total of 16 mgal with a gradient of 3 mgal per kilometer. It was also possible to confirm the Lepavina structure by geological surveys, which showed the presence of argillaceous Valenciennes strata in the center of the saddle and lignitiferous rhombohedral strata on the flanks. The only factor giving rise to some misgivings is the high value of the gravity anomalies in the center of the structure. These values are higher than in any of the deep borings to date (see list on page 31.) In comparison to the experience on the adjacent Veliki Poganec - Subotica anticline it may be assumed that Mediterranean II is no deeper than 800 meters in the center of the Lepavina structure. To judge from the experience at Veliki Poganec, however, it must also seem

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doubtful that the favorable reservoir rock of the Valenciennes layers is still present in a structure jutting up so high.

In many ways the isolated structure in the Bilo mountains south of Jagnjedovac appears more favorable; this adjoins the Lepavina structure on the West (see Profiles 11 and 12). Although no closed isogams have yet been drawn here, the terrain is wooded, hilly and difficult of access, and the few observations that have been made do not exclude the possibility that such gravity contours exist. In any case this structure between Velika Nucna and Srijem is distinctly set off from the Lepavina structure proper. According to the experience at Ludbreg and Subotica the maximum at + 22.8 mgal would allow a sufficient depth of layers promising oil at about 1000 meters. The marked southward deflection of the + 22 and + 21 mega-isogams is also deserving of notice. A secondary axis of the structure, striking from North to South, becomes clearly defined, parallel to the structure laying to the southwest of Rascani and the western limits of the Bjelovar syncline. It may be assumed that geological surveys of the structure south of Jagnjedovac could furnish additional clarifications.

(2) THE BILO STRUCTURES

While the structures just described still follow the trend of the Alps from East to West, a series of maxima, beginning east of the Lapavina structure, run along the southwestern edge of the Drava graben and are here collectively discussed under the name of the Bilo structures. Topographically the terrain is mostly wooded and hilly. Geologically almost throughout the area lignitiferous strata of the Rhomboidal layers of the Pannonian crop out on the surface.

(A) The Mosti structure (See Profiles 13 and 14).

This is a case of a structure enclosed by the concentric + 20, + 21, + 22 and + 23 ~~mgal~~ mgal-isogams. The form of the structure is somewhat irregularly triangular to heart-shaped, which obviously resulted from the coincidence of the East-West direction of the Sava river fold with the southeast-northwest direction of the Bilo mountains and the north-south direction of the Moslavina mountains. The maximum of + 23.45 mgal is located at Sredrji Mosti. Towards the northeast the gravity values sink to + 5 mgal, or a total drop of 18.5 mgal with the highest gradient amounting to about 2 mgal/km over the 5 kilometers between Mosti and Novigrad. The gravity values also fall off by 11.5 mgal towards the Bjelovar syncline on the southwest, where they reach + 12 mgal. Even towards the southeast, along the trend of the Bilo mountain range, the gravity values sill fall by 10 mgal to reach the depressions of Sirova Katalena. (See Profile 14). Delimitation from the structure south of Jagnjedovac is weakest toward the northwest for here the gravity values fall only as far as + 19.3 mgal. The broad plateau-like configuration of the southern part of the maximum makes the over-all pattern of the structure seem somewhat less favorable at first glance, but is

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probably caused by the above-mentioned interference between a number of fold directions.

In the neighborhood of Mosti the sands and clays of the rhomboideal layers of the Pannonian are everywhere encountered at the surface, frequently accompanied by lignite seams, as near Bregi, near Javorevac and near Mosti itself. It is however very noteworthy that in the summer of 1942 there was a small discharge of methane, which ignited, from a coal boring 33 meters deep near Dolnje Zdelice, about 4 kilometers southeast of the church of Mosti. The boring was on the northeastern edge of the closed gravity maximum along the + 20 ~~mega~~ mgal-isogam, about 5 kilometers southeast of the highest value of the maximum. At this point the layers are presumed to dip northward at an 8 degree angle, while in the lignite mine 1300 meters further to the North they dip to the south at an angle of 4 degrees. This gas discharge was probably connected with a gas or oil deposit whose presence in the Valenciennes layer is to be suspected. The + 23.45 mgal maximum value corresponds to a surveyed depth of about 1200 meters for the pre-Tertiary basement.

As stated, the gravity values fall off further to the southeast from the culmination near Mosti along the line of the Bilo mountain range and reach their lowest level of + 13.5 mgal near Sirova Katalena 8 kilometers northwest of this point there is a small gravity dome southeast of Sv Ana (See Profile 14). The dome is enclosed within the + 18 mgal ~~mega~~-isogams and reaches its maximum at + 17 mgal. If the larger highs of Mosti and Sedlarica should prove to be petroliferous, the examination of this small high of Sv Ana could also be considered at some later date.

The depression near Sirova Katalena has been incompletely investigated, owing to the gaps in the gravimeter network east of Bjelovar. But we must still point out, however, that there is also a topographic depression through the Bilo mountains at this place, which follows the line of the Bjelovar-Klostar railroad. Geologically, too, it is noteworthy that the gravimetric depression of Sirova Katalena lies on the northern prolongation of the synclinal axis of the Ilova graben.

(B) The Sedlarica Structure.

Southeast of the Sirova Katalena depression occurs a rise to the sharply defined Sedlarica structure. This dome-shaped structure was discovered by mapping work of Swiss geologists working for the Shell Company as early as 1923. A dome-shaped anticline, about 12 kilometers long and striking from southeast to northwest, had been located by observations of angles of dip in the Pannonian layers. Angles of dip ranging in places from 34 degrees to 42 degrees had been observed on the northeast flank, on the southwest flank these values generally run up to 35 degrees, while very locally, in the vicinity of the deep boring, they had reached 40 degrees to 46 degrees. Most angles observed, however, were under 30 degrees, while only 5 degrees to 10 degrees were noted on the exterior flanks of the dome. Based on this mapping work the Sedlarica I bore hole is that it was 855 meters deep, that at a 280 meter depth a pitch of 20 degrees was found, and from 834 meters to 349 meters [834 - 339 meters, figures as in text] the pitch was 60 to 70 degrees; that water was often encountered, and also, between 486, 387 and 616 meters small quantities of oil mixed with the water were also met (in all about 1000 literal). The exact age of the layers traversed remained unknown, however, as did the reasons why there was never any real production.

The gravity surveys made by Retrolej, Ltd. then revealed a pattern in substantial agreement with the geologically determined structure. The maximum of + 27.1 mgal was found to occur not far from the old bore hole. The structure is enclosed within the concentric + 28, + 24, + 25, + 26 and + 27 mgal. isogams and this area embraces approximately the geologically located arch layer. Up to the present time, so exact an agreement between geologic and gravity structure has been found only near Selnica. The structure is gravimetrically very prominent on three sides. The gravity falls by 24 mgal. over a distance of 8 kilometers towards the northeast and the Drava graben, which corresponds to the very high gravitational gradient of 2 mgal./km and in the upper and steeper portion - - 1.5 km wide - - of this gravity high, it even reaches 5.8 mgal./km. Towards the southwest, too, in the direction of the Zrinjska syncline, the gravity sinks by 10 mgal. from its value at the Sedlarica high. (see Profile 15), while towards the depression of Sirova Katalena on the northwest the fall is as much as 14 mgal (See Profile 16). The only direction in which there appears to be no particular demarcation is toward the southeast, but the situation is not entirely clear here, since there are gaps in the survey. At first impression the course of the + 22 mgal. isogams indicates another gravity high in the somewhat lower position of Cremusina, south-southwest of Sedlarica (See profile 18).

The particularly high value of + 27.1 mgal. for the gravity anomaly of the Sedlarica high still remains to be discussed. This is the highest value ever found for the surface level of any deep boring made in Croatia. (See table on page .....38). The gravity was somewhat lower - - + 24.4 mgal. -- at Grubišnopolje, 18 kilometers further to the south, where the micaschist layer was reached at a depth of 1029 meters. The conclusion would seem to be justified that the Sedlarica I boring would have reached the Tertiary basement a short distance beneath its lowest depth of 855 meters. Engineer Graf also reached the conclusion from gravity computations that there must be a gravitational massive body near the surface in the vicinity of Sedlarica. If the over-all gravity pattern is considered in this connection, it appears that the Sedlarica structure represents a projection of the Psunj-Papuk mass, thrust forward underground in northwesterly direction. The faulting separation of this mass from the Ilova graben runs along the fairly straight north-south line of Sedlarica-Daruvar- Pakrac - Lipik.

(C) The Structure at the Vokojevce Forester's House, South of Virovitica (See Profiles 18 and 17)

Virovitica lies on the + 4 mgal. isogam 6 kilometers south of it the gravity rises to + 18 mgal over a distance of 4 kilometers corresponding to the high gradient of 3.5 mgal./km. But then there is a pronounced flattening of this gradient in the synclinal hill-country around the Vukojevce Forester's Lodge, so that south of Rezovac the distance between the + 18 and + 19 mgal. isogams is 4 kilometers, corresponding to a gradient of only 0.25 mgal./km. Near the Forester's Lodge itself there is even a small gravity maximum on this gravity plateau, with the highest value of + 19.7 mgal. around the closed + 19 mgal. isogam. To the west-northwest from here the gravity falls to + 18.1 mgal. and thence rises to the + 27 mgal. value at the Sedlarica high. The gravity conditions on the southwest flank of the structure were not investigated, so that the over-all gravity pattern is not entirely clear. Experience at the margins of the Sava river depression - is the Gojlo and Resetari structures - as well as the conditions on the edge of the Selnica saddle have shown, however, that distinct gravity terraces can correspond to pronounced Tertiary gas and oil bearing saddle formations. The regio environs of the Vukojevce Forester's lodge therefore deserve geological investigation as to the possible existence of a promising oil structure. The gravity of + 19. 7 mgal. allows the more favorable assumption that the thickness of the Pliocene is greater, especially opposity Sedlarica.

(D) The Lisičine Structure (See Profiles 19, 20, 21 and 22.)

The Lisičine structure north of Vočin appears to be one of the most pronounced in the entire exploration area, although only the eastern half of this structure has been surveyed. The maximum, about 2 kilometers west of Lisičine, reaches the very high value of + 48.6 mgal. From Lisičine towards the south the gravity first falls to + 40 mgal, at Vočin, and then rises again, further towards the southwest, until it reaches + 44.8mgal. in the area of the basalt or augite-andesite which overlays the crystalline basement there. (See Profile 20.). It is accordingly very probable that there is an undiscovered basalt formation near Lisičine as well, and that the crystalline basement is also presumably not far from the surface at this place. As a matter of fact basalt body was recently discovered during the course of mapping works by Dr. Boljak of Zagreb. A spur of Sub-Pannonian White Marl stretching northward from the Papuk mountains is shown on the old geological maps in the Vočin-Lisičine area. This spur coincides roughly with the area of the + 40 mgal. isogams, where in any case the basement is located at inconsiderable depth. From the viewpoint of petroleous geology, therefore, the dome of the gravity structure has no significance. The same probably also applies to the Southeastward bulge between the + 30 and + 40 mgal. isogams, of the structure, towards Macute. (See Profile 22).

The Lisicine structure is gravimetrically interesting on account of its extraordinary amplitude which amounts to + 52 mgal, between its high and the Drava river depression at

Vaska, 20 kilometers farther to the north. This corresponds to a gradient of 2.6 mgal./km, gravity difference of this order has been found elsewhere in Croatia only on the southern disruption between the Psunj mountains and the Sava graben, near Nova Sradiska, between which the observed difference amounted to 51.6 mgal.

There is a northward bulge of the isogams on the northern declivity of the Lisicine structure near Gvozdansko, 3 kilometers northeast of Klisa. (See Profile 20.) Since the area involved is between the + 23 and + 26 mgal. isogams, a certain oil-geological significance would not seem entirely out of the question.

A shallowing of the gravity contours between the + 20 and + 25 mgal. isogams adjoins the northeast flank of this bulge south of cabuna. This shallowing is 3 kilometers wide, so that the gravity gradient is 1.7 mgal./km., while it is 4 mgal./km.-southwest of this strip and 4/1 mgal./km northeast of it. (See Profile 21). Thus there is a pronounced gravity terrace here as well. It might correspond to a promising structure.

On the other hand, the structure west of Klisa, formerly discovered by Dr. Papp, using geological methods, and which has been covered by a small mineral claim filed by the Bitumen Company, was not surveyed at its central part. The values found on the eastern edge of the structure show only that they lie in the approximate sone between the + 27 and + 30 mgal. isogams.

These gravity values, which are still rather high, taken together with the fairly short distance of the basement-- 8 kilometers to the south - - make the prospects of the Klisa structure seem not particularly good.

(E) The plunging axis of Bokani (See Profile 25.)

At the East-South foot of the Lisičine high, 10 kilometers east of Vočin, near Bokani, the course of the isogams suggests a small axis plunging eastward. (See Profile 23). In addition to the fact that this structure has only been very incompletely surveyed, the gravity values at + 25 to + 28 mgal. are fairly high, so that there is scarcely any chance of its being favorable for oil production.

The gravimeter station 7 kilometers southeast of this point, immediately north of Drenovac, with its reading of + 33 mgal., is probably almost at the edge of the crystalline formations of the Papuk mountains.

(F) The Mikleus Gravity Plain.

Southwest of Mikleus there is a further slight flattening of the contours between the + 18 and + 22 mgal. isogams. The gravity here rises by 4 mgal. over a distance of 3 kilometers, corresponding to a gradient of 1.3 mgal/km. In contrast to this, the gravity falls to the northeast of this strip from + 18 to + 1 mgal. over a distance of 8 kilometers, corresponding to a gradient of 2.1 mgal./km. Toward the Papuk mountains on the southwest it rises from + 22 to

31 mgal. over a distance of 2 kilometers, or a gradient of 4.5 mgal./km. For the time being no conclusion can be drawn about the possible practical significance of this shallowing for oil production.

(G) The Orahovica-Fericanci gravity terrace. (See Profile 25.)

Gravimeter surveys of this pronounced gravity terrace have been only sketchy. The geological material available, however, is better than in the areas just discussed, for the Orahovica-Benicani sheet of the 1: 75,000 map, surveyed by Dr. Poljak, was issued in 1934. According to this map, the southwest corner of the sheet is composed of basement rock, made up of mica schist, Silurian schists, and Triassic chalks. The northern end of this basement rock is a line running from East-Southeast to west-northwest, beyond which the late Tertiary commences. Of these formations, there is only a small amount of Leitha limestone and white Marl in the eastern portion, while in the remainder of the sheet Pannonian marls abut immediately upon the basement rock. This makes it probable that the boundary line between basement rock and Tertiary corresponds to a fault disruption, the more so since the Tertiary layers, according to the map, have an abnormal dip throughout towards the basement rock. A strip with Pannonian marls, about 2 kilometers wide, runs northward from the edge of the mountains, and this is then followed by overhanging sands designated by Poljak as Upper Pliocene. The most southerly gravimeter station is located on the southern edge of Orahovica, in the area of the Pannonian marls, with a reading of + 31.3 mgal. 1700 meters north of this point, in the central part of Orahovica village, in the area of the above-mentioned sands, a gravity of 25.4 mgal. was observed. There is thus the high gradient of 3.5 mgal./km over this distance. North of here however the values on a strip 3.5 kilometers broad sink only to + 20 mgal., which corresponds to a gradient of only 1.43 mgal./km. This gravity terrace of Orahovica is developed in even more pronounced fashion further east towards Pericanci, where the gravity values over a distance of 2 kilometers sink from + 22.5 to + 22.0 mgal., corresponding to a gradient of only 0.25 mgal./km. As a whole the Orahovica-Fericanci shallowing of the gravity contours coincides with the diluvial terrace in that area. The gravity falls off again to the north of the + 20 mgal. isogams, so that the + 5 mgal. isogam is reached in 6 kilometers, giving a gradient of 2.5 mgal./km. (See Profile 25.) Inasmuch as the size of the gravity values, ranging from + 20 to + 25 mgal., does not seem unfavorable, the Orahovica-Fericanci gravity terrace deserves a possible more detailed geophysical examination at some later day.

<u>(H) The Nasice Structure with its Axis Plunging toward Jelisavac. (See Profile 26.)</u>

The structure near Nasice village is pronounced, though incompletely surveyed. The maximum of + 34.2 mgal, is decidedly high. Northward from here to the Drava river, where

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the observed gravity is - 6 mgal., the value falls by 40.2 mgal., which is a large amount, even though the decent is considerably less steep than, for instance, from the Lisicine high. (See Profile 26.) But even to the south, towards the Krndja basement rock, there is at least a fall of 10 mgal. by the time the Tajnovac syncline is reached. The strong maximum of Nasice is all the more surprising, for there is neither topographic nor geological indication of its existence. The geological map (manuscript, 1: 75,000, Shee Nasice and Kutjevo, by Dr. Poljak does not even suggest it. The Nasice high is located 8 kilometers northeast of the old schists of the Ktadja mountains. The high value of the maximum - - 34.8 mgal. - - indicates, in comparison with the data for Orahovica and for Gradac, south of Nasice, that there is basement rock or heavy recent volcanic rock close to the surface near Nasice, so that the structure of Nasice proper is hardly likely to have any significance for petroleum geology.

The secondary axis plunging northeast towards Jelisavac from the Nasice structure may be somewhat differently situated in this respect, as it is developed in the region of the + 24, + 25 and + 26 mgal isogams and thus in an area where a sufficient thickness of the Tertiary sedimentary formations may be counted on. (See Profile 26.)

(I) The high of the Krndja Massif between Oradac and Oradistje. (See Profile 26)

The basement rock of the Kradja massif was traversed south of Nasice between Gradac and Gradistje, and thus near its narrow eastern end, by Engineer Graf's party coming from the north and by Dr. Schmidlin's party, laying out stations from the south. Even though these observations are hardly of any interest for oil geology, the high gravity values are still of interest for purposes of comparison with similar values in areas with unknown basement formations. From the above mentioned syncline near Tajnovac, southwest of Nasice, with a gravity of + 24.7 mgal., the values rise towards the south over a distance of 4 kilometers to reach + 42. 8 mgal. near Gradac, which corresponds to the very high gradient of 4.5 mgal./km. According to the geological map this stretch runs from Upper Pannonian to Lower Pannonian, while at the southernmost point, near Gradac, with + 42.8 mgal. the approximate boundary of the Leitha limestone would have been reached, with the overlying basalt south of Gradac on the edge of the Krndja mountains still about 800 meters away. According to the gravity value the crystalline rock or basalt must be very near the surface at this station.

Both of the northernmost observations made by Schmidlin, which were + 53.6 and + 54.4 mgal, respectively, were at the edge of the central Krndja basalt mass, facing the crystalline and Silurian schists respectively. These especially high values are to be ascribed to the heavy basalt rock. The next station to the south reaches the highest gravity value observed in Croatia: + 54.85 mgal, although this station is already further away from the basalt formation in the middle of the schistose mountains. But right at this point, as in the case of the next station to the south, with a gravity of + 51.2 mgal., an amphibolite lens comes very close, and these abnormally high values are to be ascribed to this circumstance. The next station, No 2000, near Gradistje, has a gravity of + 42.45 mgal, and is located exactly at the edge of the Kradja phyllita, facing the Pozega fault-pit. At the next station, located only 450 meters further southwest, the gravity value is only +34.95 mgal. The gradient is thus 18.9 mgal./km., which is abnormally high. In fact, it is the highest ever observed in Croatia during these surveys. This points to a juxtaposition and mutual bounding of especially heqvy and especially light rocks, at a steep displacement or fault here at the southern edge of the Krndja mountains. On the whole the conclusion can be drawn from the above data that gravities of over + 40 mgal. in this region indicate overlying crystalline or Silurian shales, and that values over + 50 mgal. indicate particularly heavy basic intercalations in this stone or else the presence of late heavy eruptive rocks. In this connection we wish to refer again to the geological interpretation of the gravity highs of + 48.6 mgal. at Lisićine and + 34.3 mgal. at Nasice.

__(K) The plunging axis of Beničanci. (See Profile 26).__

In the plain near Beničanci-Kučanci, about 15 kilometers north-northeast of Nasice, there is a large gravitational mass, plunging towards the north-northwest. It is reflected in the bulging towards the north-northwest of the isogams from + 7 to + 11 mgal. inclusive and in the marked shallowing inside these isogams. The gravity values are so low that a great thickness of the Tertiary sedimentary structures must be reckoned with. But besides this, however, the structure would need to be more closely delineated by other geophysical methods before drilling could be thought of.

3. THE REGION NORTH AND WEST OF THE MOSLAVINA MOUNTAINS.

(A) The trough north of Križevci.

South of the Kalnik mountains a gravity trough has been located north of Krizevci. This trough, of which only the eastern portion has been surveyed, is presumably connected with the graben of the upper Lonja river near Komin. The lowest gravity value observed is + 11.5 mgal. at a point 2 kilometers north of Krizevci. It is a noteworthy feature of this trough that its surveyed portion strikes from north to south and thus approaches at a right angle the Kalnik mountains, which strike from east to west. This north to south direction has been shown by the gravimeter surveys to be typical for the entire western area between Drava and Sava grabens.

(B) The Raščani structure east of Križevci. (See Profiles 27 and 28).

The Raščani high, east of Križevci, also follows this north to south direction, which is accordingly at right angles to the Lepavina high, the next structure located to the north. The high attains its maximum value of + 22.8 mgal. near Rascani, and is enclosed within the concentric + 20, + 21 and + 22 mgal. isogams. To the northwest, facing the Krizevci syncline, the drop is 11.3 mgal. ; to the east, facing the Bjelovar syncline, the drop is 11.5 mgal. (Profile 27); and to the southwest, facing the Cukovec syncline, the drop is 11.8 mgal. To the north, the demarcation from the Lepavina structure is blurred, for the values only sink to as far as + 19.2 mgal. at the gravity pass of Sesvete (Profile 28), and to the south as well there is only a narrow gravity threshold to the Moslavina massif, which attains a small maximum at Farkacevac, where the value is + 19.05 mgal. The Rascani high belongs accordingly to a spur running down northward into the plains from the Moslavina mountains.

Geologically all that is known about the Rascani area is that layers of the Rhomboid stage crop out on the surface together with lignite measures, the strike and low angle of dip of which agrees with the gravity pattern, as, for instance, at Lemes. It is also worth noticing that the small mineral claim filed there by Bitumen Ltd., which was presumably laid out on the basic of geological studies, exactly coincides with the center of the Rascani structure.

From the standpoint of oil geology, the somewhat indeterminate form of the maximum, the low gravitational gradient in the region of the dome, and the fairly long distance from the deep Drava and Lonja-Sava grabens are all factors which

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appear ab initio less favorable. Presumably any further exploration of this structure will first have to await good results from the adjacent Lepavina, Mosti and Vrbovec structures.

(C) The Bjelovar Syncline.

A fairly large syncline, striking from southeast to northwest, was discovered in the Bjelovar area, between the Bilo structures on the northeast, the Moslavina mountains on the southwest, the Rascani structure on the northwest, and the Grugisnopolje structure on the southeast. Large portions of its eastern section remain unsurveyed. It is about 30 kilometers long and about 10 kilometers wide. The lowest gravity values are in the neighborhood of +11 and + 12 mgal., which are considerably higher than in the Drava graben or in that of the Lonja and Sava rivers. In its northeastern section the north to south course of its western flank, which immediately adjoins the Rascani structure, is worthy of notice. In the southwest, west of Grubisnopolje, there is a connection with the Ilova river depression. In this area confirmed showings of oil and gas have been known, only in the Bilo structures, northeast of the Bjelovar graben, which structures adjoin the deep Drava depression on their northeastern flanks. For this reason it has not been proven whether or not formation of oil and gas has occurred within the Bjelovar graben.

(D) The Cazma-Vrbovec axis. (Profiles 29 - 32)

The Cazma-Vrbovec axis commences 2 kilometers northeast of Cazma with a gravity of + 27.4 mgal. This point is located on the northwest corner of the crystalline mass of the Moslavina mountains. According to the latest geological map, sheet Ivanic Klostar and Moslavina, this northwest corner of the crystalline mass would, it is true, run about 2 kilometers further south. But it will be explained below that according to the results of the gravimeter survey, it is highly probable that the crystalline mass of the Moslavina mountains on the north runs far beyond the limits hitherto assumed. And inasmuch as readings over + 27 mgal. at points in the southwest corner of the Moslavina mountains are certainly over crystalline formations, this is also presumably the case with the point showing + 27.4 mgal. gravity at the northwest corner of the massif. From there a plunging anticlinal ledge over 18 kilometers long strikes first towards the northwest, then to the north-northwest and finally almost due north. From Cazma the structure then passes about 3 miles south of Dubrava and then proceeds in the direction of a point about 3 kilometers northwest of Vrbovec. During this portion of its course, the structure first crosses the swampy downstream areas of the Cazma river, then the low hilly terrain near Dubrava, then the flat moorland graben of the lower Glogovnica brook, and ends finally in the hilly terrain of Vrbovec. There is thus no connection at all recognizable here between topography and structural geology, which connection for instance does quite clearly exist in the case of the Gojlo structure and, at least in suggestive fashion, with the Kriz structure. There are certainly no geological clues in the swampy lower reaches of the brook, and hardly any in the low rolling surfaces of the rest of the structure, which is covered by deep layers of clay and loam.

This is the status of the gravity pattern for the time being. Three sections of the structure can be distinguished:

(1) The section between the + 27 mgal and the + 15 mgal. isogams. (See Profiles 29 -30.)

Here we have less a structure proper and more the northwest slope of the steeply descending west and north flanks of the Moslavina mountains. According to the results of observations near Mikloušķa, it appears possible that oil accumulation has also occurred along these flexural flanks.

(2) The section between the + 15 mgal. and the + 13 mgal. isogams. (See Profiles 29 and 31.)

Here we have a plateau-like flattening in the course of the structure. From here the gravity values fall by 1a mgal. over the 8 kilometers distance to the depression of the upper Lonja, near Luka. This corresponds to a gradient of 1.5 mgal./km. There is a fall of 6 mgal. over the 4.5 kilometers of the distance northward towards the Cugovac syncline north of Dubrava, corresponding to a gradient of 1.3 mgal./km. In this part of the structure the gravity is at the same level as on the dome of the Sumecani-Kriz structure adjoining/on the south. There the Valenciennes layers may be assumed, from the results of counterflush drilling to lie at depths between 500 and 1200 meters, and for the time being similar depths may be counted on the section of the Cazma-Vrbovec structure we have been discussing.

(3)

The third and northernmost section of the structure, lying between the + 13 and the + 8 mgal. isogams, is the most noteworthy of all. (Profiles 29 and 32). The structure here is narrow and sharply defined, with steeply descending flanks. The drop towards the Luka syncline in the west amounts to 10.5 mgal. with a gradient of 2.5 mgal./km.; towards the narrow Dubrava syncline in the east, which roughly coincides with the lower course of the Kamesnica potok, it is 4 mgal. with a gradient of 2 mgal./km. According to the isogam pattern, there would even seem to be a small closed gravity high on the crest of the saddle, with a maximum of + 10.6 mgal. and a closed + 10 mgal. isogam. But the observations have not been so closely spaced here as to make the existence of this closed high seem entirely certain. The + 10 mgal. isogam of this little high could also be linked up, without too much doubt or strain on the imagination, with the + 10 mgal. isogam 1.5 kilometers further to the southeast, and it would thus assume the same form, stretched out towards the northwest, that the + 9 mgal. isogams now have. But even if this second interpretation should be in order, and there were thus no closed gravity structure, the narrow, elongated form of the gravity pattern would point to the possibility of there being a closed geological structure here as well. The structure seems especially interesting for oil geology, because so pronounced a gravity structure has not elsewhere been found at such a low gravity level. It is true that Osekovo and Struzec lie on a gravity level comparable to that of Vrbovec, but the structure of Osekovo shows a much less sharply defined isogam pattern that does that of Vrbovec. The Valenciennes layers would also be suspected to occur in the Vrbovec structure at a depth between 1000 and 1800 meters, according to the analogy of Osekovo. The objection might be raised for a moment that the Vrbovec structure might lie too far from the promising Drava and Sava troughs. In fact, however, the Vrbovec structure immediately adjoins the deep Lojnica graben (-0.9 mgal.), which represents the direct geological continuation of the Sava graben. So in any case the Vrbovec structure should be borne in mind as a promising location for a deep exploratory drilling.

(E) The Vrtlinska axis on the Western Flank of the Moslavina Mountains. (Profile 35).

From the point near Vrtlinska, with gravity + 20.9 mgal., which is located, according to the geological map, 2 kilometers west of the western edge of the Moslavina massif, the axis plunged toward the point + 13.2 mgal. 6 kilometers further to the west, on the gravity pass near Susnjari. More -

over, the representation of this structure depends to a very great extent on interpolation from more distant series of observations and is therefore not certain in its details. Under certain circumstances oil accumulation might well be possible, in itself, in similar structures located on the flanks of ancient massifs.

(F) The Kriz - Sumecani - Ivinic Klostar. (Profiles 33-35.)

The Kriz-Sumecani-Ivanic Klostar axis has a certain relation with the structure we have just described. The former strikes from southeast to northwest for a distance of 18 kilometers along the northern fringe of the Sava graben. It reaches its highest gravity value of +14.25 mgal. at the village of Sumecani between Ivanic Klostar and Kriz. The closed + 14 mgal. isogam surrounds this point, while the closure of the following + 13 mgal. isogam in the southeast does not appear absolutely certain. To the southwest, toward the Sava graben, the gravity falls to + 7 mgal. over a distance of 2 kilometers, corresponding to the high gradient of 3.5 mgal./km. In contrast, however, the gravity sinks only to + 11 mgal. towards the Marcani syncline on the northeast which corresponds to a gradient of only 1 mgal./km. (See Profile 34.) The Sumecani structure is thus developed in strongly asymmetric fashion, with weakly developed northeast flank. The structure pitches slowly in a northwestern direction, so that + 8.3 mgal. is observed near Ivanic Klostar, and + 6 mgal. near Brecec. (See Profile 35.)

Since the gravimeter surveys had the character of reconnaisance surveys, and since moreover it was not clear whether the axis of the geological structure exactly coincided with that of the gravity structure, and further than that it was also unknown which Tertiary layers lay beneath the diluvium, the structure of the area was investigated by means of 20 counterflush drillings. This is thus one of the few examples in Croatia to date in which it can be seen to what extent in detail the gravity pattern coincides with the geology structure of the area and to what extent it does not. (See 1: 250,000 map attached.) According to these drillings, the general structural geology does agree with the gravity pattern. Geologically, too, there is a relatively steep slope towards the southwest, while the region of the dome and the northern slope is very flatly developed. Further than that, the slow pitch of the saddle towards the northwest in the direction of Ivanic Klostar was also reflected in the geology. But on the other hand, the geological center of the structure was shifted about 2 kilometers to the north of the gravity center. Moreover the isopypsal lines of the geologically determined marker horizon of the boundary between Paludinan and Congaries layers did not run at all parallel to the isogams. Thus the principal horizon was encountered in well South No 25 near Ivanic Klostar, at the + 9 mgal, isogam at elevation 80 meters above sea level, while on the same isogam, southwest of well South No 12, the principal horison is surely lower than - 200 meters beneath sea-level. The gravity pattern also failed to reveal anything about a fault striking from southwest to northeast, with a vertical displacement of about 40 meters, which the drillings showed as probable. The rather slight extent of the agreement between gravity pattern and geological pattern is perhaps due to the presence of various heavy rock bodies in the crystalline basement complex. In the near-by Moslavina mountains there are particularly heavy gabbro masses alongside of light granites and gneisses. The fact that the older, friable, sandy marls of the rhomboidal layers probably have a somewhat lower density than the younger and often cohesive clays of the Paludinan layers may also contribute to the irregularities. In any case the agreement between geophysics and geological structure is less in the Sumecani structure than in the more sharply defined and steeper structures at Selnica and Sedlarica. It is an illuminating fact that in general the agreement is higher better in the more pronounced structures. Thus the example of Sumecani may serve as a warning against assuming too intimate a relation between gravity pattern and geological structure in structures known only from gravity data, and not the sharply defined at that. In such cases, before the commencement of deep drilling, detailed geological or geophysical studies still remain desirable.

It was found, with respect to the relation between the depths of the layers and the gravity values, that the boundary between Paludinan and Rhomboidal layers is located at depth 50 meters at the dome of the structure, where gravity is +14 mgal. If we assume thicknesses similar to those at Gojlo, the

Valenciennes layers would be encountered at Sumečani be-between 350 meters and 1150 meters.

Moreover the occurrence of gas in various counter-flush borings shows the geophysical indications of the Križ structure to have been basically sound.

(4) The Moslavina Mountains and their Environs.

The Moslavina mountains appear on the existing geological maps as a relatively small mass of crystalline rock of characteristically triangular shape. The gravimeter surveys approached the western edge of the massif from the west, while they remained at a greater distance from the north-eastern and southwestern edges. (See 1: 200,000 map, Sheet 1,) Three traverses even penetrated for some distance into the interior of the massif from the southern tip near Mikleuška Brook. Near Mikleuška itself a gravity of + 29.45 mgal. was noted at the approximate boundary between Leitha limestone and gneiss. The next value, observed 1600 meters further north, at the boundary between Leitha limestone and gneiss, reaches the very high level of +30.85 mgal. (See Profile 35.) Further to the north, the gravity falls off slowly again, so that in the middle of the gneiss, 4 kilometers north of this point, + 27.4 mgal. was noted. A gravity maximum of + 30.85 mgal. thus occurs at the point + 30.85 mgal., which is geologically however, composed of entirely heterogeneous components, in that the steep south flank, with a gradient of 5 mgal./km., marks the rift between crystalline formations and the Tertiary fault-pit, while the easily sloping north flank with a gradient of 1.2 mgal./km., is the result only of petrographic differences within the crystalline formations.

Two particularly high gravity values were observed about 2 kilometers to the west, on the Novo brdo, south of Jelenska gornja. According to the geological map the southern station, with + 31.3 mgal., still lies in the Levantine, while the northern station, with reading of + 29.2 mgal., is in the Leitha limestone. This is very improbable. At the very least the southern station must lie in the Pannonian, which the draftsmen simply forgot to enter on the old Croatian map between Leitha limestone and Levantine, here on the west flank of the Moslavina massif. It is the most probable that both of these points lie on Leitha-chalk which is probably underlain at shallow depth by crystalline formations. The point +31.3 mgal., located 3 kilometers to the east, forms the center of the geologically heterogenous gravity maximum we have been discussing. In any case both of these instances reveal the surprising fact that the highest gravity values are found here, directly on the southern edge of the crystalline massif, while the gravity falls off again to the north, towards the inside of the massif, as far as the survey has gone.

This is also confirmed by the following traverse to the west, in the valley of the Jelenska gornja. (See Profile 36.) Proceeding from the south, the station + 26.9 mgal. probably still lies in the Pannonian, and the succeeding maximum value of +29.95 mgal. in the Jelenska gornja proper is probably on shallow Leithe limestone underlain by crystalline formations. The next three stations to the northward, at which the gravity sinks from + 27.9 to + 24.45 mgal., lie at the approximate boundary between Leitha limestone and crystalline formations, and the four northernmost stations of the traverse, at which the gravity sinks from + 25 to + 21.6 mgal., lie in the area of a granite strip imposed on the gneiss of the Moslavina mass. West of this traverse there are two other stations, both of them in the valley of the Pescenica Brook, that still come in contact with the crystalline formations. According to the geological map, the western station, with + 21.35 mgal., is on the boundary of the crystalline rocks, while the eastern station, with + 23.45 mgal., lies in the gneiss.

To sum up, values ranging from + 21.5 to + 31.3 mgal. were found on outcropping crystalline bedrock complex at the southwestern tip of the Moslavina mountains. These rather high differences are obviously of purely petrographic origin. The low values from + 21.6 to + 25 mgal. [page 64] fall within the realm of the lighter granites, while the higher values are found in a region of gneisses distinguished by the frequent occurrence of heavy amphibolite schist and gabbro intercalations.

Similar gravities were noted elsewhere in areas with considerably greater thickness of the tertiary formations above the basement rock. Thus, for example, the reading near

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the oil outcroppings near the former axle grease factory at Mikleuska was about + 24 mgal., and the old bore hole, which was about 900 meters deep,had apparently not yet reached the bottom of the Tertiary rocks. If we compare more distant locations, the bottom of the Tertiary at Sedlarica, with gravity + 27.1 mgal., is deeper than 860 meters., and at Grubisnopolje, with a gravity of + 25.4 mgal., Tertiary formations 1025 meters thick were encountered over the basement rock. These examples should serve as warnings against estimating the probable depth of the basement rock in areas not thoroughly studied, on the basis of gravimeter readings alone. It is, nevertheless,a fact that at the southwestern corner of the Moslavina mountains values over + 28 mgal. have been found only on crystalline formations or on shallow layers of Leitha limestone imposed directly upon such formations. Further than that, the area of exposed crystalline formations is characterized by low gravity gradients. It follows from these general indications that the Moslavina massif probably extends far beyond its presently assumed eastern boundaries, and that it is not triangular in shape but rectangular, with edges striking approximately north to south and east to west. (See Sheet 1 of the 1: 200,000 map.)

In conclusion we summarize for purposes of comparison the gravity values observed immediately above outcropping crystalline and those of the Psunj, Krndja and Prosara Mountains.

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Granites of the Moslavina Mountains	+21.6	to	+ 25.0 mgal.
Gneisses of the Moslavina Mountains with basic intercalations	+25.0	to	+31.3 mgal.
Gneiss Island of Bijela Stijena on the western edge of the Psunj Mountains	+27.45 mgal.		
Amphibolite schist on the southern edge of the Psunj Mountains	+34.6	to	+38.6 mgal.
Gneisses and amphibolite schists on the northeastern edge of the psunj Mountains/	+37.75	to	+38.0
Phyllite and silurian schists of the Krndja Mountains	+40	to	+50
Basalts and amphibolite schists of the Krndja Mountains	+50	to	+55
Gneiss, phyllite, and green schists of the Prosara Mountains	+18	to	+25
Granites of the Prosara Mountains	+14	to	+18 mgal.

(A) The West Flank of the Moslavina Mountains.

From the western edge of the crystalline, its western gravity flank also runs trends from north to south and slopes down rather steeply towards the west. The reentrant trend of the southerly portion of the west flank towards the east, so striking on the geological map, is only faintly expressed in the gravity pattern. To some extent this may probably be ascribed to an outcropping of the crystalline rock at slight depths under the shallow cover of Leitha limestone. In the northern part of the west flank near Cazma, the gravity drops from + 27 to + 12 mgal. over a distance of 5.5 kilometers, corresponding to the fairly high gradient of 2.7 mgal./km. At the southwest tip the values even fall by 23 mgal over a distance of 6 kilometers from + 31.3 mgal. south of Jelenska gornja down to + 8 mgal. near Popovca, corresponding to the high gradient of 3.8 mgal./km. (See Profile 36.) The above Cazma-Vrbovec structure, which we have already described, extends northwestward from the northern end of the west flank, and, somewhat further to the south, the Vrtlinska structure, likewise earlier discussed by us, and with which the Kriz-Sumecani-Ivanic Klostar structure is also connected, stretches to the west. The southernmost part of the west flank does not continue on its north to south trend but instead parallels the nearby Sava trough from northwest to southeast.

(B) THE NORTH FLANK OF THE MOSLAVINA MOUNTAINS WITH THE IVANSKA PROJECTION. (SEE PROFILE 38).

According to the Ivanic Klostar-Moslavina sheet of the geological map, the northern edge of the crystalline formations of the Moslavina mountains should be sought along the line running from southeast to northwest from Gornja Gareznica to Cazma. But north of this line almost the only formations shown are glacial drift, with the exception of two rather small Leitha limestone areas near Podgaric and Samarica. The observations made by Engineer Farztsch, however, show a considerable gravity maximum, with values running as high as +30.3 mgal, for quite a distance north of this line in the Ivanska section. (Profile 38.) In the immediate neighborhood of this high there is a very feeble gravitational gradient down to the +27 mgal isogam. The descent becomes steeper only after that isogam. It is probable, judging by the situation we have described at the southwest corner of the Moslavina mountains, that the area enclosed by the +27 mgal isogam near Ivanska also rests on outcropping basement rock which has only been lightly covered by glacial drift. The Leitha limestone bodies of Podgarmes and Samarica would then probably lie in a canal-like channel of basement rock, similar to that between the Psunj and Papuk mountains. This view is also supported by the fact that according to F. Koch the Leitha limestone of Samarica does not slope away normally to the north from the basement rock, but instead slopes southward towards the mountains at an angle of 20 degrees from the basement.

The most characteristic feature of the north flank of the Moslavina mountains is the rather narrow Ivanska projection of the gravity field which juts out towards to the north. This gravity spur, after descending steeply towards the north, turns sharply eastward. The western part of the north flank of the Moslavina massif runs more from east to west, and there are only a few steep gravity gradients towards the Bjelovar syncline. Here too, at the westernmost station, 2 kilometers east of Cazma, the traverse has probably just re-entered the area of outcropping crystalline rocks again; the gravity here is +27.4 mgal. We have already pointed out the gravity ledge from that runs northward from about the middle of the north flank of the Moslavina massif, over the small gravity high of Farkacevac, to the Rascani structure.

(C) THE SOUTH FLANK WITH THE BRSLJANICA AND GARESNICA AREAS (PROFILES 39, 40 and 42.)

The layers, and also the isogams, at first turn sharply north-northeastward from the southwest tip of the Moslavina massif, near the oil outcroppings in the gneiss near Mikleuska. The acute angle thereby produced in a narrow pencil of isogams is one of the most pronounced and striking features of the gravity pattern throughout the entire region surveyed. The +29 mgal isogam passes the church standing on Leitha limestone to the east of Mikleuska; 1.2 kilometers further east, the +26 mgal isogam passes the oil seeps of Srpsko Selisce, which lies in the White Marls and not, as might appear from the geological map, in the Paludinan layers (Profile 39). According to the geological map, the edge of the crystalline runs further northeasterly to reach the eastern edge of the sheet 3 kilometers north of Brslanica mala. But gravimeter surveys show the high value of +30.9 mgal in Brslanica itself, about 4 kilometers south-southeast of here, and 30.7 mgal 1500 meters to the west of that point. South of these stations there is then a pronounced shallowing of the gravity contours down to the +28 mgal isogam (See Profile 40.) As compared with the situation north of Mikleuska it is probable that the crystalline is present in this area under the diluvium or under a shall Tertiary cover. The crystalline would in that case, of course, extend about 7 kilometers further to the south than is shown on the geological map, and this should be checked on the terrain itself if at all possible. Further to the east the isogams then veer to the northeast, so that Garesnica lies on the +25 mgal isogam. This locality, at which gas has shown, is probably also not far away from the southeast corner of the Moslavina crystalline formations.

The isogams run in a pronounced west to east direction south of the +28 mgal isogam near Brslanica, so that this is also the principal direction of the south flank of the Moslavina massif. This pencil of isogams then makes a sharp bend in the Kutinica area and passes over into the isogam group striking north-south, to the east of Mikleuska.

A western and an eastern section can be distinguished in the region of the south flank of the Moslavina massif, which flank strikes from west to east. The line of demarcation between these sections roughly coincides with the boundaries between the Ivanic Kostar and Moslavina sheet and the Sisak and

Sunja sheet of the 1:75,000 map, on the one hand, and those between the Daruva and Pakrac and Jasenivac sheets of the same map, on the other hand. In the western section (Profile 42) the isogams fall strongly and continuously to the Sava depression on the south. In the course of this decline, the gravity sinks over a distance of 10.5 kilometers from the +26 mgal isogam to that of +5 mgal or a fall of 21 mgal in all, corresponding to the very considerable gradient of 2 mgal/km. On the way there is a distinct shallowing of the gravity contours, about 1 kilometer wide, between the +15 and +16 mgal isogams near Sartovac, northwest of the Gojlo structure. (See Profile 42). Since oil showings are said to have been formerly noted near Sartovac, this shallowing may be significant for oil prospects. In contrast to this phenomenon, however, the +17 and +18 mgal isogams are crowded together on the north fringe of this shallowing, which may perhaps be due to a fault striking north and south.

In the eastern part of the south flank of the Moslavina mass, there lies:

(b) THE GOJLO STRUCTURE (PROFILES 40-41)

From the gravimetric point of view, the Gojlo dome, which is well defined geologically and is oil and gas bearing, represents a low undulation superimposed upon the general slope of the gravity contours on the south flank of the Moslavina mountains. From +28 mgal, half way between Brsljanica and Bogaza, the gravity falls by 11 mgal over this distance of 3.5 kilometers to reach +17 mgal, corresponding to the high gradient of 3.1 mgal/km. (Profile 40) A strong subsidence of the Tertiary layers must be assumed in this zone. Then follows the broad and shallow gravity-contour trough of the Disnica valley, which exactly corresponds to the already known geological syncline north of the Gojlo anticlinal arch. The lowest gravity in this gravity trough is +15.6 mgal (and perhaps even +14.95 mgal.) The axis of this gravity trough lies 2 kilometers north of the geological anticlinal axis of the Gojlo structure. The gravity trough is about 5 kilometers long, and it finally disappears towards both east and west by lifting itself out and passing over into the general gravity slope toward the south.

The Gojlo gravity high follows to the south of this trough. It is marked by the closed +17 mgal isogam, upon which are superimposed a few small local highs within the +18 mgal isogam +18.35 mgal is the highest gravity noted on the Gojlo structure. It is about 1600 meters from the trough to the +16 mgal isogam. Accordingly the gradient on the north flank of the Gojlo anticlinal arch only reaches the low level of 1.5 mgal/km, while the Paludinen layers at the surface here dip northward at the relatively steep angles of as much as 20 degrees. While geologically the southern flank follows a course fairly symmetrical with that of the northern flank, this is not at all the case with the gravity pattern. There is an unbroken strong fall of the gravity values from the +18 mgal isogam at the dome of the Gojlo synclinal arch to the Sava trough on the south, so that in 4.5 kilometers the +3 mgal isogam is reached, giving a gradient of 3.5 mgal/km. The gravity pattern of the south flank of the Gojlo structure is thus far more pronounced than that of the north flank.

Since, on the whole, the gravity patterns reflect the general architectural pattern of the buried surface of the basement rock, it must be assumed that the basement rock beneath the Gojlo structure is only feebly arched upwards, and that it then sinks abruptly towards the south. The Gojlo anticline is therefore not a formation with a thick mass of basement rock at its core between two deep gravity troughs, of which the best example in the region under study is furnished by the Selnica anticline. The Gojlo saddle is rather only an undulation -- though a strong one -- in the Late Tertiary, above a levelling off or even a ledge in the descent of the basement rock on the southern flank of the Moslavina massif.

If we consider in greater detail the gravity pattern in the dome region of the Gojlo structure, we find that on the whole it is similar to the structural geology. The closed +17 mgal isogam coincides to some extent with the core of the geological structure -- a core consisting of congeria beds and Lower Paludina layers. However the axis of the gravity high is displaced, has a northward displacement of about 300 meters as compared with the geological axis. (See Profile 40.) The east-and-west side of the +17 mgal isogam coincides almost exactly with the boundary between the Lower and Middle Paludina layers, and accordingly the area enveloped by this isogam has a blunt shape similar to that of the geological body. Only to the northeast does the +17 mgal isogam form a projection jutting out in this direction, which corresponds to a slight outward east-northeastward bulge of the geological axis in this region, which counterflush drilling has recently revealed. To the west the spurlike prolongation of the Gojlo structure towards the west-northwest appears to be reflected in a sharp bend of the +16 and +17 isogams. Moreover, the west flank of the anticlinal arch, gravimetrically considered, plunges more steeply than does the east flank. To the west the +14 mgal isogam is already reached within 1 kilometer west of the +17 mgal isogam, while in the east the +15 mgal isogam is only reached after 2.5 kilometers. In any case the Gojlo structure soon passes over, on both west and east, into ghe general gravity slope to the south, broken however by the presence along the Medjuric-Garesnica road of a broad gravity-contour terrace leading to the Medjuric-Janjalipa gravity-contour ledge on the east-southeast.

The small local highs at the highest dome of the Gojlo structure attain an amplitude of only 0.5 mgal and thus lie near the limits of accuracy of gravimeter observations. They are therefore probably of no geological significance.

The producing oilwells on the south flank of the Gojlo structure are located between the +15 and +18 mgal isogams. Thus to the south they pass beyond the area of the outermost closed isogam, that of +17 mgal. This proves the possibility of oil accumulation in the Croatian area under study even outside of closed isogams. The sinking of the gravity by 4 mgal from +18.35 mgal at Well G 8 to +14.4 mgal at Well G 13, corresponds to a sinking of the layers by 125 meters. A fall of 1 mgal thus corresponds to a fall of 30 meters in the layers here, while at the Selnica anticline it was found to correspond to about 100 meters. This may probably be explained by assuming that the upper edge of the crystalline rock dips more steeply at the south flank of the Gojlo structure than it does in the Pannonian.

It should still be observed that the gravity observations furnish no proof for the existence of a local high on the south flank of the Gojlo structure, as was assumed during the first mapping of that structure by Dr. Sommermeier. This assumption was disproved, however, by subsequent geological mapping by the Geological Department of Petrolej, Ltd.

For purposes of comparison with the gravity values, we present the profile of Well No. 4 at Gojlo, which was started at the +17 mgal isogam:

0-70 meters	70 meters	Lower Paludinan Layers
70-316.5 meters	246.5	Rhomboidea Layers
316.5 - 665	348.5	Upper Sandy Valenciennes Lower oil and gas horizons
665 - 1045	380	Lower Argillaceous Valenciennes Layers
1045 - 1154	109	White marl
1154 - 1182.5	28.5	Bituminous shale; Sarmatian
1182.5 - 1490	307.5	Mediterranean II
1490 - 2025	535	Oligo-Miocene lacustral formations
2025 - 2146	121	Red argillites and cretaceous Conglomerates; Rubbler layers
2146 - 2155.3	9.3	Albite-Diorite; Crystalline basement Rock

In the upper parts of the core hole the angle of dip ranged from 15 degrees to 20 degrees down to about 700 meters. At the upper edge of the Sarmation it was very low, being only 8 degrees, but then increased to an average of about 50 degrees in the lower parts of Mediterranean II and in the Oligo-Miocene lacustral layers, where in places the dip of the layers dipped so sharply as to become vertical. Numerous striations and zones of autoclastic breccia here traversed the rock formations. It is thus probable that the deeper parts of the bore hole had encountered the steep flexural zone of the Early Tertiary that accompanies the disruption of the crystalline rock of the Gojlo terrace with respect to the deep Sava river trough.

According to geological observations, the total thickness of the Paludina layers should be estimated at roughly 700 meters to the south, at the edge of Ilova village, with gravity +8 mgal. The depth of the crystalline basement rock here can be suspected to be around 3000 meters. This agrees with the results of seismic reflection shooting, for good reflections were still obtained from the 2700-2800 meter level, halfway between Ilova and Gojlo Well 4, approximately at the +12 mgal isogam. The situation at Osekovo Well 1, which is located at the +10 mgal isogam, and where the crystalline basement rock may be thought to be at depth 2800 meters, also does not fit in badly with this assumption of 700 meter thickness for the Paludinan.

At the synclinal axis of the Sava trough, south of the Gojlo structure, the gravity is +1 mgal. The above considerations lead us to assume that the depth of the crystalline rock is about 3600 meters at this place. The question still remains open as to what tertiary layers are intercalated between

Ilova village and the syncline line. It may be surmised that they are less Paludinan layers than Pannonian horizons. There can also be new sand horizons among them, which takes off at the Gojlo dome and may have thus made oil accumulation possible.

(E) THE EAST FLANK OF THE MOSLAVINA MASS WITH THE VELIKA TRNOVITICA STRUCTURE. (PROFILES 43 and 46)

The east flank of the Moslavina mass is composed of two sections: a southern section, in which the isogams bulge out strongly towards the east, and a northern section, in which they run from south to north.

The southern section continues the situation described for the adjacent area of Garesnica and Brsljanica. We may also assume here that the highest isogam observed, that of +28 mgal, marks the approximate edge of the crystalline formations, which are, nevertheless, entered on the Daruvar sheet of the geological map as being located at Prokop, about 9 kilometers farther west.

From here, at the +28 mgal isogam, there is a steep eastward descent to the Ilova graben, the synclinal line of which passes east of Garesnica with a gravity of +15.4 mgal (Profile 43). This drop in gravity occurs over a distance of 6 kilometers, giving a gradient of 2 mgal/km.

The Velika Trnovitica structure extends northeastward from the northeast corner of the Garesnica gravity-contour bulge, at about the gravity level of the +20 mgal isogam.

This structure is especially characterized by the peculiar hammer-shape of the +18 mgal isogam, which encloses an extensive gravity-contour shallowing. (Profile 44). Even though this structure is located at the same gravity level at the Gojlo structure and also, according to the geological map, there is a fairly large-sized area, especially to the west of it, that has Pannonian layers, the small gravity-drop to the adjoining synclines makes oil prospects doubtful, as does the proximity of the far less promising Grubisnopolje structure.

The northern section of the east flank of the Moslavina massif adjoins the Ivanska high, which probably consist of crystalline rocks, and which we have already described. The isogams here strike from south to north and point exactly towards Bjelovar. Toward the east, over a distance of 4.5 kilometers, the gravity falls from +26 mgal isogam to +17 mgal, a gradient of 2 mgal/km. (See Profile 46.) The deepest part of this drop towards the Bjelovar syncline was not surveyed.

5. THE ILOVA TROUGH

It was already clear in former days that a zone of tertiary depression, the Ilova trough, must run between the Moslavina and Psunj-Papuk mountains. But it was only the gravimeter surveys that for the first time furnished any information about its dimensions and architecture. The axis of the trough runs due north, and it is nearer the Moslavina mountains than to the Psunj-Papuk. In the south, at first, the Medjuric-Janjalipa gravity-contour ledge forms a demarcation against the Sava trough. Then follows the rhombic syncline of Gaj, whose shape results from the intersection of the Ilova trough with a smaller syncline striking from east to west. At this point the gravity is +10.4 mgal, which is the lowest value reached within the Ilova trough. It may be assumed from the results of the Janjalipa I boring that the depth of the basement rock here is about 2,200 meters. In contrast to this, the gravity values of -2 mgal in the Sava trough, south of the Ilova trough, and +4 mgal in the Drava trough, north of the Ilova trough, should be noted. The Ilova trough is thus not of the same dimensions as the great synclines along the Sava and Drava rivers. From the Gaj syncline the gravity even rises, and rather fast at that, to +15 mgal to the northward, along the synclinal axis of the Ilova trough. The tectonically deepest part of the Ilova trough then remains at this gravity level for the next 16 kilometers to the north. This section of the Ilova trough is narrow and almost resembles a valley. Finally there is a further climb at +17.5 mgal to a kind of a gravity-contour pass near Ladislav. From here on the gravity sinks once more to reach +11 mgal in the southern bulge of the Bjelovar syncline. It has already been pointed out, earlier in this paper, that the fall in gravity near Sirova Katalena, on the chain of the Bilo mountains, probably marks the point of connection between the Ilova trough and the Drava syncline.

(A) THE GRUBISNOPOLJE STRUCTURE. (Profiles 47-46)

The Grubisnopolje structure extends northwestward from the northwest corner of the Papuk mountains, which are formed of Triassic rocks and granite, into the Ilova trough. This structure, which reaches its highest gravity of +25.3 mgal in the northeastern part of the town of Grubisnopolje, is enclosed within the +25, +24 and +23 mgal isogams. The gravity drop toward the flanks is in general small; for instance, on the south side the gravity falls from +25.3 mgal only as far as +21 mgal over a distance of 8 kilometers, corresponding to a gradient of only 0.5 mgal/km. (See Profile 47.) The sharpest drop is still on the northeast flank, where the gravity values sink by 4 mgal over a distance of 1 kilometer. (See Profile 47.) On the whole, however, the Grubisnopolje structure is more of a scutellar gravity-contour arching than a pronounced gravity structure. In the center of the structure the Grubisnopolje I Well was drilled, encountering the following profile:

Drilling Depth Meters	Thickness Of Layers Meters	Designation
0 - 72	72	Diluvium
72 - 148	76	Lower Paludinan Layers
148 - 544	396	Rhombohedral Layers
544 - 829	285	Upper Sandy Zone of the Valenciennes Layers
829 - 980	151	Lower Argillaceous Zone of the Valenciennes Layers
980 - 1028.6	48.6	Leitha Limestone; Mediterranean II
1028.6 - 1036.65	8	Biotite Schists of the Basement Rock.

The Tertiary layers, with a dip ranging from 5 degrees to 8 degrees, were almost horizontal in the entire boring.

Next to the slight thickness of the Valenciennes layers and the absence of the Sarmatian, the greatest surprise of the whole drilling was the unexpectedly early arrival at the crystalline basement rock at a depth of only 1028.6 meters. In contrast to this, in the drilling at Sedlarica, about 19 kilometers to the north, the basement rock had not yet been reached at a depth of 860 meters, although the gravity at the top of the well was +27.1 mgal or 1.7 mgal higher than that at Grubisnopolje. On the other hand, though, we have seen that the gravity at stations located directly on granite, at the southwest corner of the Moslavina mountains, ranged only from +21.6 to +wt +25 mgal. The reason why the gravities at Grubisnopolje are not even higher is probably that the rhombohedral layers there are thick and very friable and thus presumably only slightly developed. Thus, even if there is no very intimate relation between the gravity values and the depth of the pre-Tertiary basement rock, the data we have presented still show that already at readings over +20 mgal -- and by all means with values over +25 mgals -- it is entirely possible that the basement is less than 1000 meters below the surface.

The small gravitational gradients on the flanks of the Grubisnopolje structure also indicate that it is more likely to be a weak ledge of the basement rock than an anticlinal uplift of the Tertiary formations with features markedly favoring petroleum accumulation.

(B) THE DARUVAR LEDGE WITH ITS LATERAL AXES NEAR BRESTOVAC AND DEZANOVAC (PROFILES 49-51)

A gravity-contour ledge stretches westward from Daruvar into the Ilova trough. It is south of the Grubisnopolje structure and is separated from it by a shallow trough in the neighborhood of Koncanica. This ledge has one culmination towards Brestovac on the northwest and one towards Uljanik on the southwest. The stations in this area, however, were very widely spaced, so that the details of the gravity pattern do not stand out very sharply with any particular degree of sharpness. In Daruvar itself the very high gravity of +43.45 mgal. was observed. At this place there are a few Triassic stacks with transgressing Leitha limestone outcropping to the surface; these are western spurs of the Papuk mountains. As is seen, the gravity here is even considerably higher than on the granites and gneisses of the Moslavina mountains. But by the time the next station is reached, 1 kilometer to the west, it has already fallen back to +34.85 mgal. and in another 1400 meters westward it reaches +28.65 mgal. (Profile 49). This corresponds to the very high gradients of 8.6 mgal/km and 4.4 mgal/km respectively. Only at the south edge of the Krndja massif was a gradient higher than this observed; in that case it amounted to 18.9 mgal/km. At Daruvar, also, this abnormally high gravitational gradient points to a fault displacement of the Tertiary with respect to the Triassic basement rock. West of the station in question, however, the gradient flattens out considerably (see Profile 49), and, especially between the +25 and the +24 mgal. isogams, near the Ivanopolje glass works south of Brestovac, there is a space 3 kilometers wide in which a structure could be located. (See Profile 51.) From this area two secondary axes radiate toward the northwest and southwest. Northwest of Brestovac, along the northwestern axis, in an area where the gravimeter stations were spaced especially far apart, another broad shallowing of the gravity contours seems to appear between the +22 and +21 mgal. isogams. (Profile 50.) Along the lateral axis pointing toward the village of Uljanik, a similar shallowing near the village of Dezanovac, between the +22 and +21 mgal. isogams, was observed, using stations somewhat more closely spaced. (Profile 49.) From this structure towards the west the gravity falls by 6 mgal. over the 3 kilometers to the Ilova trough, corresponding to the not exactly slight gradient of 2 mgal./km. Toward the south, over the 7 kilometers to the Gaj syncline, the gravity falls by 9 mgal., corresponding to the gradient of 1.3 mgal./km. Nevertheless, the basement is probably somewhat deeper than at Grubisnopolje. Since, moreover, Dezanovac is already considerably nearer than Grubisnopolje to the Gojlo-Janjalipa-Bujavica area, and thus to the whole area of the Sava trough, a later more detailed examination of this area might be considered.

(C) THE LIPIK-BUJAVICA-JANJALIPA-MEDJURIC GRAVITY AXIS, WITH ITS LATERAL AXES SOUTH OF BUJAVICA. (PROFILES 52-55.)

From Daruvar to Pakrac the isogams trend from north to south, parallel to the slope of the Papuk-Psunj mountains and to the Ilova trough. The survey, however, was not carried all the way to the edge of the outcropping basement rock, so that the highest isogam of +33 mgal. still passes about 1 kilometer to the west of the projecting chlorite schist stack of Kusonje, north of Pakrach. South of Pakrach the isogams from +15 to +30 mgal. project to the west in a section about 10 kilometers wide, in front of the Psunj mountains proper, thus distinctly marking a subsurface spur of these mountains towards the West. This gravity-contour spur is divided by a not very clearly defined gravity trough, striking from east to west in the neighborhood of Subotska into a northerly Lipik-Bujavica-Janjalipa gravity ledge and a southerly Dolnji Cagljic-Kricke-Paklenica gravity ledge. While the southern ledge clearly made its presence known, even in earlier days, both topographically by hilly terrain over 400 meters high and geologically by the second southward projection of the Leitha limestone and the White Marls, the northern ledge runs into the Pakra lowlands and is lost, and was only discovered by the gravimeter survey.

The highest gravity value of this Pakra gravity ledge was +36.35 mgal., observed in the east, between Pakrac and Lipik, near outcropping Leitha limestone. (Profile 52.) +33.05 mgal. was noted near Lipik itself, whose mineral springs originate in the ravines from the Leitha limestone, which has been tapped near the surface by shallow borings. From here the gravity drops sharply toward the Gaj syncline on the north and somewhat less sharply towards the Subotska syncline on the south. Along the gravity axis itself there is at first a fairly strong gradient towards the north-northwest, so that the +15 mgal. isogam is reached near Bujavica over a distance of 10 kilometers corresponding to a gradient of 1.8 mgal./km. (Profile 52.) Judging by the results of the drilling near Bujavica, this upper portion of the gravity axis hardly promises oil, since the depth of the basement rock is insufficient.

The Bujavica gas field lies on the southern slope of the gravity ledge on a small local gravity axis, discovered by means of the torsion balance, between the +14 and the +15 mgal. isogams. (Profiles 53-54). The Bujavica 9 boring here encountered the following profile:

DEPTH OF SECTION IN METERS	THICKNESS OF SECTION IN METERS	DESCRIPTION OF SECTION
0 - 257	257	Rhombohedral Layers
257 - 551	294	Valenciennes Layers
551 - 588.6	37.6	White Marl
588.6 - 613	24.4	Sarmatian
613 - 752	139	Mediterranean II
752 - 1331	579	Oligo-Miocene Lacustral Layer
1331 - 1332.1	1.1	Granite

Thus in spite of the fact that the gravity is 2.5 mgal. lower near Bujavica than in the Gojlo area, the Pannonian and Mediterranean are both much less thick than at Gojlo, and the crystalline basement rock is accordingly much closer to the surface. In comparison with Grubisnopolje as well, where the gravity is 11 mgal. higher, the depth of the Bujavica basement is surprisingly slight. The only explanation that might perhaps be found would be that the granites of Bujavica are especially light in comparison to the dioritic rock of the Gojlo structure and the biotite schists of Grubisnopolje.

Near the village of Bujavica a small axis, plunging to the south, diverges almost at right angles from the main gravity ledge; this axis manifested itself at the time of the special geological mapping through a convex southward bulging of the layer boundaries. (Profile 54.)

The southward course of this branch can be followed distinctly until it reaches the +10 mgal. isogam. To judge by the Janjalipa situation, the Pliocene could be considerably thicker here than in Bujavica gas field. Accordingly it is entirely possible that new gas and oil bearing sands may be intercalated here.

The gravity ledge ends, for the time being, a short distance west of the drilling field at Bujavica, and continues again 2 kilometers further to the north, in the shape of the Janjalipa structure. (Profiles 52 and 55.) The highest gravity value -- about 14.5 mgal. -- is reached by the latter 1.5 kilometers west of Brezine. This point is surrounded by the closed +14 mgal. isogam. This high is connected towards the southwest, near Brezine, by way of a shallow gravity-contour pass, with the Lipik-Bujavica gravity ledge (Profile 52); while to the south it is separated from the gravity axis of Bujavica by a weak minimum. Only in the north is there a greater drop -- about 4 mgal. -- towards the Gaj syncline. (Profile 55.) A sort of a gravity-contour dike or embankment leads west over the area north of Medjuric to the Gojlo high. (Profile 52.)

The Janjalipa high also manifested itself very distinctly in the seismic reflection shooting as a layer saddle near the mill west of Brezine.

The deep drilling Janjalipa I was sunk on the western edge of the closed high at about +13.8 mgal. It yielded the following profile:

0 - 10 meters	10 meters	Diluvium
10 - 40	30	Lower Paludinan Layers
40 - 327.5	287.5	Rhombohedral Layers
327.5 - 840	512.5	Upper Sand-bearing Valenciennes Layers including gas sands from 737.3 to 740 m. and from 748.0 to 753.0 m.
840 - 1020	180	Lower Argillaceous Valenciennes Layers
1020 - 1089	69	White Marl
1089 - 1116	27	Bituminous Marl-Shale; Sarmatian
1116 - 1144.3 meters	28 + x	Mediterranean II

The Valenciennes layers were thus developed in far greater thickness -- 692 meters -- in the Janjalipa I boring than at Bujavica. Thereby the upper edge of the tortonian came to lie at 1116 meters depth at Janjalipa as against only 613 meters at Bujavica. This difference is surprisingly high in view of the difference in gravity, which only amounts to 1 mgal. There must be geologically a major disruption between these two borings -- a dislocation with no visible effect on the gravity pattern. It is possible that the Oligo-miocene lacustral layers are not developed in such great thickness at Janjalipa as at Bujavica (where the thickness is 58 579 meters) and that in that case the crystalline basement rock is not located the whole 560 meters deeper that one might be tempted to suspect from the altitude of the upper edge of the Tortonian. The crystalline basement rock could also be heavier at Janjalipa than at Bujavica by analogy with Gojlo. In any case the situation we have described shows that even very considerable faults, and even where the depth of the basement rock is not particularly great, need not always and under all circumstances show up on the gravity pattern. And it should also be borne in mind that the gravimetric survey of this region was not confined merely to widely spaced gravimeter observations, but that closely-spaced torsion-balance observations were made as well, and that these too showed no gravity-contour displacement.

The gravity dike we have already mentioned, which is about 1 kilometer wide, runs between the Janjalipa and Gojlo highs. (Profiles 52 and 56.) The details of this pattern were secured not by gravimeter but by torsion balance. Along the axis of the gravity dike, the gravity sinks, at first slowly, from the Janjalipa high, until it reaches the value of +12.26 mgal. about 1 kilometer north of Medjuric. From that point on the gravity slowly rises again up to the area of Sv. Duh, at the southeast foot of the Gojlo. There is a high gravity gradient

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from the gravity-contour bridge toward the Sava trough on the southwest. This gradient is particularly steep in the northwest, at the section bordering on the Gojlo structure. (Profile 56.) Here the gravity falls from +12 mgal. to +0.5 mgal. over a distance of 7.5 kilometers corresponding to a gradient of 1.5 mgal./km. To the north, the gravity dike of Meduric blocks off the Ilova trough, or as the case may be, the southern section of that trough -- the Gaj syncline -- from the Sava trough. Here the gravity values fall from +12.2 mgal. over a distance of 3 kilometers, only as far as +10 mgal., corresponding to the slight gradient of 0.7 mgal./km. The Janjalipa-Medjuric gravity-spur is, for this reason, a completely asymmetric structure. The gravity dike is geologically very clearly expressed in the strong westward projection of the Paludinan layers from the Brezine area to the road halfway between Poljana and Medjuric.

The Janjalipa II bore hole was drilled north of Janjalipa at about +12.4 mgal. on the gravity-dike. This drilling, which had to be stopped on account of the danger from partisans, thus lies about 1.5 mgal. deeper than the Janjalipa I bore hole and as was expected, met the various layers about 100 meters deeper.

6. The Tertiary Hill-Country North of the Sava, on the Line Lipovljani-Novska Okucano-Brod.

(a) The Kozarica Structure (Profile 58).

This structure, mapped by Doctor Bohm in 1939, lies on the gravity-contour slope that descends from the Lipik-Bjavica gravity ledge down to the Sava trough. There is no gravity high in the structure. Small bulges of the +7 and +8 mega-isogams run close by the geologically discovered structure on the south. These two isogams then cross the structure from southeast to northwest. There is, however, a gravimetric indication of the structure in that these isogams then diverge near Novi Grabovac, at the northern part of this structure, onto a strip about 1 kilometer wide, and that there is even a gravity-contour terrace 3 kilometers wide northeast of the structure between the +8 and +10 isogams. Thus, even though the Kozarica structure seems only indistinctly defined as compared with the Gojlo structure, the manifestation of both these structures in the gravity pattern as terrace-like shallowings in a gravity-declivity is not essentially different, as will be seen at once by comparing Profiles 40 and 58.

The lower to middle sections of the Paludinan layers were located by geological means on the outer flanks of the Kozarica structure. It is not known with certainty which substage of these layers outcrops at the center of this structure.

It can be assumed from the geological data that the layers at the center of the Kozarica structure lie about 300 meters deeper than in the Janjalipa I bore hole. The Kozarica structure lies gravimetrically about 6 mgal. deeper than that of Janjalipa, and accordingly a greater difference of stratigraphic depth than 300 meters would ordinarily be looked for. Taking everything into consideration, the Kozarica structure, which is represented as a closed dome by the geological map, deserves an investigation by exploratory drilling.

(B) The Lipovljani Structure (Profiles 56-57).

For geological reasons the presence of a structure was suspected near Lipovljani, where gases occasionally showed in well-borings. For this reason, not only gravimeter surveys were made there, but also very detailed torsion-balance observations. However, the latter only furnished immaterial additions to the gravimeter pattern. The gravity anomaly manifests itself in a southwestward projection of the +2, +3 and +4 isogams, and in a gravity-contour shallowing about 1500 meters wide between the +5 and the +4 isogams. The upper section of the Upper Paludinan layers probably outcrops to the surface. For this reason, as well as on account of the low gravity values, which are only 2 to 4 mgal. above those existing on the nearby trough axis of the Sava trough, the structure would have to be a very deep-lying one, which would of course explain its indistinct gravimetric development. In any case it would be desirable to make sure by geological methods (shallow drilling) of the actual existence of a closed structure before starting deep drilling. Except for the Resetari structure (+9.2 mgal.) no other structure of all those studied in Croatia up to now lies at so low a gravity level. This would not be per se unfavorable.

<u>(C) The Dolnju Cagljic-Kricke-Paklenica Axis (Profile 59).</u>

The maximum value of +30.5 mgal. was observed near Dolnji Cagljic, which lies upon white marl, according to Doctor Sommermeiser's geological mapping. From here a traverse 7 kilometers long was run towards the gneiss island of Bijela Stijena on the southwest. But here the gravity does not rise, as might have been expected, but on the contrary falls off a little, so that values between +28.35 and +29.2 mgal. were noted above Mediterranean II and with +27.45 mgal. over the gneiss of the island itself. This is just another example that shows that structural geology does not by any means necessarily always have to be in agreement with the gravity pattern. The gravity of +27.45 mgal. on outcropping granite is in line with the readings on the outcropping granites of the Moslavina mountains (page 65).

From Dolnji Cagljic to Kricke, on a line where the upper parts of the White Marl consistently crop out to the surface, the gravity falls from +30.5 to +22.85 mgal. This may well be taken to indicate the probability that, towards the west, thicker and thicker layers of the Early Tertiary (Mediterranean II and Oligo-miocene Lacustral Formation) as intercalated between the White Marls and the basement rock. Over this distance of 5 kilometers the gravity falls by 7.65 mgal., which corresponds to a gradient of 1.5 mgal/km.

The gravity axis then proceeds beyond Kricke towards value of +13 mgal at the oil seepage in Sisvete Forest, north of Palenica Paklenica. (Profiles 59-60.) At these seepages, the shallow drilling previously done probably met the Sarmatian under the White Marls, which are here about 30 meters thick. Between Kricke and Sisvete, which is about 5 kilometers, the gravity falls by another 10 mgal, which corresponds to the rather high gradient of 2 mgal/km. But the gradients to the north and south from the oil seeps are much more considerable. The gravity falls to +1 mgal over the 3 kilometers to the village of Paklenica on the south, which corresponds to the high gradient of 4 mgal/km (Profile 60). Along this stretch the White Marls, Vallenciennes, Rhombohedral, Lower, Middle and Upper Paludinan Layers all crop out to the surface. On account of the narrow width of the outcroppings and the high gravitational gradient, these layers must drop away at steep flexures and faults, and it is possible that petroleum accumulation occurs in these flexures and faults.

Over the 4.5 kilometers to Novska on the west, the gravity falls from -13 to -2 mgal corresponding to a gradient of 2.4 mgal/km (Profile 59). The Dolnji Cagljic-Krickie axis does not, therefore, as might a priori be suspected, continue plunging slowly towards the west into the Sava trough, but instead is sharply displaced with respect thereto. The precipitous break in the gravity contours towards Paklenica in particular surely corresponds to a pronounced faulting in the crystalline basement rock with respect to the Sava trough. This gravity-contour precipice then continues further to the east along the Psunj mountains.

Surface outcroppings of the white marls occur at the oil outcroppings of Sisvete. According to the profiles of the old hand drillings, which were 60 to 100 meters deep, dark bituminous clays, dark clays with depositions of white marl, and "oil sands" were encountered beneath them. These deep layers probably belong in the Sarmatian, which is the presumptive source rock of the entire area. This allow position of the source rock makes it improbable that there are accumulations of oil or gas in economically useful amounts either at the oil outcroppings themselves or in the tectonically higher locations along the Sisvete-Kricke-Dolnji Cagljic axis.

It is also worth noticing that the Sisvete oil seeps are on the same gravity level as the Janjalipa I deep hole, which is not very far away. While the boundary between White Marl and

Sarmatian at Sisvete is probably around the 50 meter depth level, it is at 1,089 meters depth in the Janjalipa I deep hole. Here too, then, no parallelism between gravity pattern and structural geology can be found. Again, the low gravity at Sisvete, in spite of the outcropping of so deep a layer as the White Marls, could perhaps suggest that the Sarmatian Mediterranean II and Oligo-Miocene Lacustral Formations are all developed in far greater thickness here, in a peripheral area of the Sava trough, than is the case on the gravity spur of Janjalipa.

It might have been suspected on a priori grounds that the Dolnji Cagljic-Kricke-Sisvete axis, which is so very well developed both geologically and gravimetrically, would have continued westward for some distance yet into the Sava plain. And the gravimeter readings, at least in the area of the zero and -1 mgal isogams west of Novska, do in fact seem to point to something of the sort. (Sheet 1 of the 1:200,000 map.) The torsion-balance observations, however, fail to confirm this. In any case no indication of a continuation of the gravity ledge can be found in the area between the Sisvete oil seeps and Novska.

(D) The Golese-Dolnji Raic Profile (Profile 61).

Gravity is +19.05 mgal in the north near Golese, probably in the neighborhood of outcropping Leitha limestone.

From here to the station 1800 meters to the south it sinks only as far as +15.85 mgal. This point lies in the Sarmatian, according to the Pakrac-Jasenovac sheet of the old Austrian manuscript map, which is more clearly delineated in the Tertiary formations and is also obviously more accurate in some places than the later Yugoslav edition of this sheet. As early as 1875, Neumayer and Paul mention sandstones and finely laminated shales with carbonized fossil plants, which in any event should be placed in the Sarmatian, as occurring in the adjacent valley of the Luka Brook. According to them these layers dip south-southwestward at angles from 45 degrees to 55 degrees. At the last-mentioned gravimeter station, too, a steep southward gradient commences, so that the -3.1 mgal isogam is reached at Dolnje Raic, 3.6 kilometers away, corresponding to the high gradient of 5.4 mgal/km. The vertical attitude of the Lower Paludinan layers, observed by Neumayer and Paul at the nearby Gornji Raic, agrees with this, The marginal displacement of the Tertiary layers with respect to the Sava trough is thus still very steeply developed with respect to the topographical Sava depression, even at Gornji Raic and Dolnji Raic, at the edge of the hilly terrain. The gravity curve flattens out only from here, so that the -10 mgal isogam is reached after 4 kilometers in the neighborhood of the Sava trough, making the gradient still amount to 1.8 mgal/km even here. (Profile 61.)

(E) The Bijela Stijena-Benkovac-Okucani Profile. (Profile 62.)

As we have already mentioned, +27.45 mgal was observed on the gneiss of the basement-rock island of Bijela Stijena. Towards the south, then, the foraminiferous marls of the Tortonian follow first in the valley of the Slobostina Potok. Then come Leitha limestone, Sarmatian, and White Marls. At the boundary between Sarmatian and White Marls, south of Benkovac, the gravity is +6.25 mgal, so that up to this point there is the high gradient of 5.3 mgal/km. No clear picture of the structure of the Pliocene in the lower portion of the Slobostina Valley can be gained from the existing maps. For the first kilometer the value drops sharply to +1.8 mgal, so that even here the gradient is still 4.5 mgal/km. But then there is a considerable shallowing, and at Okucani, 3.5 kilometers further to the south, the reading is -8.5 mgal, corresponding to a gradient that is still 3.0 mgal/km. Over a distance of 2.5 kilometers from Ojucani, the gravity drops still further to -13 mgal, since here, at Bogicevci Dolnji, is the deepest section of the Sava trough.

(F) The Sagovina-Medare-Dolnji Bogicevci Profile (Profile 63).

At the north this profile embraces the basement rock massif of the Psunj. In Sagovina, on the edge of the outcropping amphibolite schist, the gravity is +27.95 mgal. 1600 meters south of this point it reaches +6.5 mgal. The gradient here is thus the most abnormally high one of 14 mgal/km. Only locally, at the southern edge of the Krndja mountains (see pages 53-54) has a comparable gradient been observed. Especially thick and especially light masses must thus have been placed, by an abrupt disruption alongside of the heavy basement rock. This is also the conclusion reached by the existing geological maps in this area. The southern edge of the Psunj mountains amphibolite schists' striking perfectly straight from west to east on the Pakrac-Jasenovac and Pezega-Nova Gradiska sheets, is already enough to suggest a major faulting. It is moreover very strongly indicative of this that there is no Leitha limestone shown on the map along this edge of the amphibolite schists. Leitha limestone could not fail to be noticed even by a hasty cartographer. The Pannonian, too, is entirely or partly missing on the surface here, since Paludinan layers are shown up to a distance of about 500 meters from the edge of the basement rock. It is obvious that the situation here is entirely different from that in the Slobostina Valley, where the Miocene juts out far to the south, and accordingly the drop in gravity is not so abrupt. Thus while the margins of the Croatian Tertiary troughs usually have a flexural structure, there is in this case a sharp displacement on the southern margin of the Psunj mountains, which recalls the marginal fissures of the Rhine Valley graben in southwest Germany. According to the experience there, a major disruption of ancient mountains with respect to the Tertiary formations is not particularly favorable for petroleum accumulations. Parallel displacement further into the tertiary, or are more favorable, as are structures somewhat more removed from the peripheral fractures, such as occurs at Resetari, located a little further to the east. From the latter point, with +2.6 mgal, this gravity falls to a gravity minimum of -13.65 mgal at Dolnji Bogicevci, 6 kilometers to the south, thus giving a gradient of here of only 2.7 mgal/km. There are no indications of the existence of any localized gravity structure to be noted in the course of the profile. The low of -13.65 mgal at Dolnji Bogicevci is the lowest observed in Croatia. The total gravity difference from the starting point of the profile, near Sagovina, amounts to 41.55 mgal, with a mean gradient of 5.54 mgal/km. Both values are unusually high. (See table on page 25.) Greater gravity differences are to be found only on the next profile to the east, that of Sumetlica-Nova Gradiska, and in the profile through the eruptive masses from Lisicine to the Drava trough, while the mean gradient of 5.54 mgal/km is the highest ever observed over the course of an entire profile in Croatia.

Judging from the results of the Resetari I drilling, the thickness of the Tertiary formations at the deepest point of the Dolnji Bogicevci syncline may be estimated at about 3500 meters.

(G) The Sumetlica-Gernik-Nova Gradiska-Sava Valley Profile (Profile 4).

The three northernmost stations of this profile lie upon the amphibolite schists of the Psunj mountains and show the high gravity values of from +34.66 to +38.55 mgal. According to the size of these anomalies, therefore, they must lie between the gneisses of the Moslavina mountains and the ancient schists and basic eruptive rocks of the Krndja mountains. (See table on page 65.) These high values are explained by the high specific gravity of amphibolite schists, which is usually rich in magnetite. H. Rosenbusch, in his Elements of Petrology gives 3.008 to 3.065 as the specific gravities for actinolite schist and hornblende schist, and 2.695 to 2.786 for gneisses.

The gravity then falls over the distance of 1 kilometer between the third and fourth stations of the profile from +34.6 to +24.75 mgal, a drop of roughly 10 mgal. The gradient is thus of comparable order to that on the southern precipice of the Psunj mountains, near Sagovina, in the preceding profile. The faulting disruption of the Late Tertiary from the amphibolite schist of the Psunj mountains must have occurred in this place. It is true that according to the Pozega-Nova Gradiska sheet of the geological map the fourth station would still lie on the amphibolite schist, but the gravity value shows that this point in reality is already south of the disruption. Following the profile further to the south, the descending slope of the gravity values gradually levels off, to some extent, but it still continues to be steep, until the ninth station, about 2.5 kilometers north of the Cernik church, is reached, so that the reading at this point is -2.5 mgal. The difference between this value and that of the third station, which still lies upon amphibolite schist, amounts to 37.15 mgal, corresponding to an average gradient of 2.5 mgal/km. Up to this point, therefore, the downthrow of the bottom of the basin is very steep and very abrupt. The pattern shown by the geological map agrees with this. For along the line of this profile, south of the crystalline formations, only narrow zones of Leitha limestone and the Pannonian crop out along the line of this profile, while the Paludinan layers commence already at a distance of about 500 to 1000 meters from the edge of the crystalline and continue for the remainder of the profile.

There is a marked bend in the gravity curve at the ninth station, in the northern part of Cernik (Profile 64). From this point to the axis of the gravimetric trough, 6 kilometers away, the gravity sinks only to -12.95 mgal, or a difference of 10.44 mgal, corresponding to a gradient of 1.75 mgal/km.

The gravity curve is particularly flat between the ninth and tenth stations. In this section the traverse probably crosses the axis of the Resetari anticline. This anticline manifests itself in the gravity curve profile only through a particularly flat course of the gravitcurve, as will be shown in the discussion of the profile through Resetari. But here near Cornik this shallowing is less clearly expressed than at Resetari, and consequently the anticline itself at the southern edge of the shallowing, in the old coal mine of Resetari is probably also less distinct. Neumayr and Pauk already observed that the angle of dip of lower Paludinan layers was from 55 degrees to 60 degrees towards the south-southwest trough. Neumayr and Paulk also located the middle section of the upper Paludinan layers at Kovacevic, at the entrance to Nova Gradiska. According to the present state of our knowledge, this would correspond to about the -10 mega-isogam. 3 kilometers south of Nova Gradiska, the axis of the Sava trough is already reached at Prvca, with a gravity of -12.9 mgal.

(H) The Podvrsko-Bacindol-Resetari-Vrbje Profile (Profile 65).

This profile begins in the village of Podvrsko, a little south of the crystalline basement rock. The northernmost three stations, with readings of 30.5, 27.7 and 25.85 mgal respectively, still lie on Leitha limestone, according to the geological map. The drop in gravity that commences here

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then continues uniformly at first, until the ninth station is reached, where the gravity is +14.8 mgal. A glance at Profiles 64 and 65 will show that the downward slope of the gravity is considerably less steep here than on the corresponding section of the Sumetlica-Cernik profile. This is caused by the fact that the profile in question lies within the topographical and geological depression between the Psunj and the Povega mountains. The gravity even rises a little at the tenth station, so that here, near Opatovac, there is a weak maximum. (Profile 65.) Only Pannonian without further subdivision is shown here on the geological map. But it is precisely in this area that a new geological mapping would seem to be required. The gravity then sinks slowly to reach 11.05 mgal at the oil outcroppings near Bacindol. Here, beneath the diluvium, Mediterranean II may crop out, but it is rather more likely to be Oligocene conglomerate, which is very prevalent in the Povega mountains. The gravity falls precipitately to 3.05 mgal at the next station, 1 kilometer further to the south - thus by 8.0 mgal. This gravity precipice is almost as high as at the marginal disruption between amphibolite schist and Late Tertiary near Sumetlica. Accordingly a strong fault disturbance must similarly pass through this area a little to the south of Bacindol. Geophysics thus confirms the faulting which must also be assumed for geological reasons and which explains the occurrence of the oil seeps at Bavindol. The dislocation runs further in an east-southeast direction along the end of the Pozega Mountains, and has also been detected by the northernmost stations of the following two gravity profiles.

Still further to the south, in the neighborhood of the deep well Resetari I, there is a pronounced shallowing of the gravity curve. -2.9 mgal was observed at the deep well itself, -1.75 mgal 600 meters further north, and -3.05 mgal about 450 meters further to the south. The geologically distinct anticline of Resetari, with its steep flanks, does not manifest itself as a maximum on the gravity pattern, but merely as a shallowing of the gravity curve in its general downward slope towards the Sava trough. In contrast, the Selnica anticline, as we have seen, towers 23.3 and 23.6 mgal over the deep synclines to the north and south. On the other hand, the conditions at Gojlo are similar to those at Resetari to the extent that the Gojlo anticline, too, only manifests itself as a weak maximum superimposed upon the general drop in gravity towards the Sava trough. Thus the gravimetric investigations has demonstrated that the structures of Gojlo and Resetari should not be considered anticlines of the first order, with a core of heavy rock in the depths, but rather manifestations of undulations in the Late Tertiary, which are superimposed upon the subsidence, in fault-disruptions of the basement rock, from the marginal mountains as far as the Sava trough. This explains the fact that the lower portions of the deep drillings at Resetari and Gojlo do not show the normal horizontal orientation of the layers that is shown by the mapping to exist near the surface at the axis of the anticlinal arch, and which would also be expected in the deeper cores of normal anticlines, but show instead very steep and distorted attitudes of the layers. This makes it readily understandable that a whole series of anticlines and synclines one after the other is not to be observed at the edge of the Sava depression, as is the case with normal folded mountain formations, but only a single anticlinal uplift, and even that fully developed only in some places. Petroleum geology, however, sees such a marginal upwarping as especially favorable, for at the strong fault displacements at the edge of the Sava trough the oil and gas rises from the probable Sarmatian source rocks at the core of the trough and accumulates in the structures of the marginal anticlinal uplift.

The following is the profile of the deep well Kesetari I, sunk at the surface gravity level of -2.9 mgal:

0 - 74 meters	7.4 meters	alluvium and diluvium
7.4 - about 30	22.6	congeria beds
30 - 484.8	454.8	valenciennes layers
484.7 - 1501.25	1016.5 meters	white marls

Thus in spite of the fact that this well was sunk from a point with the lowest gravity value of all Croatian deep borings to date (see table on page 38) the lower edge of the

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Valenciennes layers was neverhtheless encountered closer to the surface than in the other deep borings. On the other hand, the drilling through the White Marls, in spite of the very great apparent thickness of 1016.5 meters, corresponding to an actual thickness of about 670 meters, had still not reached their bottom. At the location of the drilling, the bottom of Mediterranean II can be assumed to lie at about 20000 meters depth and the crystalline basement rock at about 2600 meters. Thus, in spite of the especially low gravity value at Resetari, the total thickness of the Tertiary is probably not much greater there than for instance at Gojlo, where the gravity is +18 mgal. This illustrates once again the exceptionally small low gravity in the Dolnji Bogicevci basin, to the peripheral zone of which the Resetari area belongs.

The southern flank of the Resetari anticline drops steeply towards the Sava trough, according to the geological data and also to seismic reflection observations. In this area the gravity falls first from -3.05 mgal to -3.95 over a distance of 400 meters, thus with a gradient of 2.2 mgal/km and then over the next 400 meters to -5.8 mgal, on a gradient of 4.6 mgal/km. Even though these gradients seem extremely moderate in comparison with those further to the north in the same profile, near Bacindol, they are still, as the table on page 25 shows, quite as strong as for instance on the steep northern slope of the Ludbreg structure down to the Drava trough, at the great Steinberg fault in the Ostmark. Only to the south of the last-named station (-5.8 mgal) does the gravity curve flatten out again until it reaches the synclinal axis in the Sava valley, where, about 5 kilometers south of the Resetari I deep well, the gravity is -11.5 mgal. Seismic reflection shots then showed that here, too, the attitude of the tertiary sediments, down to greath depths, is very slightly inclined away from the horizontal.

(I) The Doreznik-Bunjevoi-Adjamovoi-Sava Valley Profile (Profile 66).

The profile commences in the north at Doreznik, with a gravity of -11.6 mgal observed on outcropping Leitha limestone transgressing upon the Oligo-Mjocene Lacustral Layors of the Pozega Mountains. Over the distance of 1100 meters to the third station the gravity falls to +2.9 mgal, thus by 8.7 mgal. This corresponds exactly to the gravity-contour precipice near Bacindol, met in the last profile. This probably means, geologically, that the Leitha limestone and the Pannonian imposed on it plunge steeply like a flexure to the Sava trough.

The profile continues southward with a regular and gradually flattening course. An isolated shallowing on the eastern prolongation of the Resetari axis, which probably crosses the profile near Gunjevoi, between the stations -1.6 and -3.56 mgal, is hardly noticeable.

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(K) The Tisovac-Ostri-Vrh-Staro Petrovo Selo Profile (Profile 67).

This profile runs from the Pokotina Potok on the edge of the Pozega mountains via Ostri Vrh and Staro Petrovo Selo into the Sava Valley. The very strong fall in the gravity between the first three stations, from +9.65 to +0.6 mgal, or a drop of 9.05 mgal. over a distance of 1 kilometer, corresponds again to the steep downward slope of the Leitha limestone at the marginal flexure of the Pozega mountains, along the continuation of the Bacindol disturbance. In the further course of the profile, there is still a distinct flattening near the village of Osgri Vrh, in the area of the -5 mgal isogams. At this point the profile even intersects a small maximum with the value -4.35 mgal. On Sheet 2 of the sketch map 1:200,000 sketch map, this weak axis to the west of Ostri Vrh appears as a small undulation of the -5 mgal isogam, and a second such undulation is also present to the southeast of Ostri Vrh. For the time being, no more definite conclusions can be drawn about the geological significance of these relatively small-scale anomalies. But a certain similarity with the gravimetric conditions at Resetari allow the inference that similar if more feebly developed geological structures may also be present here. There is however no immediate connection with the oil outcroppings located 2.5 kilometers further west in the White Marls. From here to the synclinal axis of the Sava Valley the gravity falls by only 3.5 mgal more, to reach -8.5 mgal; since at this location the trough of Bolnji Bogicevci again gradually rises towards the east.

(L) The Profile from the Ostri Vrh Oil Outcroppings to Staro Petrovo Selo (Profile 68).

This profile begins in the White Marls near Ostri Vrh, a little north of the oil outcroppings and runs via Ostri Vrh and the eastern part of the village of Staro Petrovo Selo into the Sava valley. In the north the profile does not quite reach the Pozega mountains or the marginal Leitha limestone. The oil outcroppings themselves lie in an area of gravity +1.5 mgal where gravity values sink at a moderate pace. The Lipovljani structure, for instance, lies at a comparable gravity level. But there the White Marls are first encountered at the 1500 meters depth, while at Ostri Vrh they crop out to the surface. It will be seen once again from this that the area of the trough of Dolnji Bogicevci and its environs represents a region of especially low gravitation. Further than that, the layers of the White Marls are shown by geological observations to pitch rather sharply at the oil outcropping area towards the Sava trough, and this is fully confirmed by seismic reflection shooting.

Immediately to the south of the oil outcroppings, the gravity sinks only slowly, then more rapidly until it reaches the level of -6.65 mgal at Staro Petrovo Selo, and then finally weakly once more until the trough axis, where it is -8.5 mgal.

(M) The Pozega Mountains

The three last profiles lie on the southern edge of the Pozega mountains. Even if the gravimeter traverses did not penetrate to the inner area of this small group of mountains, they still surrounded it by a narrow framework, from which a fairly clear gravity pattern emerges. Geologically the Pozega mountains are not formed mainly of crystalline rocks, like the other marginal mountains around the Sava trough, but of conglomerates, sandstones and marls, which, according to the results of the drillings at Bujavica 9 and Gojlo 4, probably belong to the Oligo-Miocene Lacustral Formations. In the western part of the mountains the gravity values are thus correspondingly at relatively low levels ranging from +10 to +20 mgal. More ancient formations crop out to the surface only in the northeastern part of the mountains, south of Pozega. In the neighborhood of the central axis of the mountain group these consist primarily of a number of small chalk bodies. This chalk, according to the Pozega sheet of the 1:75,000 geological map, adjoins on the north, immediately to the south of Pozega, an elongated andesite massif that includes small amounts of gneiss. According to the recent investigations of Baric (Report of the Croatian State Geological Institute, 1942, page 27) the crystalline basement rock is in reality more prevalent there than andesite. The fact that especially high gravity values ranging from +30 to +34.45 mgal were observed near Pozega itself agrees with this view. These values are intermediate between those noted on the gneisses of the Moslavina mountains and those on the amphibolite schists of the Psunj mountains. (Table on page 65.)

On the whole, the gravity pattern of the Pozega mountains agrees well with the geological conditions. There is a strong gravity drop towards the Sava trough on the south, from +35.45 to -5 mgal. Within the area of this drop occurs the steep, precipitous zone of Bacindol-Tisovac, which we have already discussed, which appears to shallow out further to the east, where only few gravimeter observations have been made. There is similarly a sharp gravity drop towards the fault-pit of Pozega on the north, though it does not go so deep as the gravity-cliff to the south, for the values here sink from +34.45 to +14.25 mgal. (Profiles 69-70.) Especially in the upper part of this gravity-cliff, directly south of Pozega, the gravity falls from +33.2 to +19.35 mgal over a distance of only 2 kilometers, corresponding to the very high gradient of 6.9 mgal/km. A strong and steep fault may accordingly be assumed here too, on the northern edge of the Pozega mountains. (Profile 69.)

At the western and eastern ends of the Pozega mountains there are both topographically and tectonically pass-like formations. Depressions. A gravity-contour pass on the northwest, near Bolomace, 10 kilometers west of Pozega, corresponds to these, though it is locally somewhat displaced. Its gravity is +16.4 mgal and from here the values rise towards the west and east, while they sink towards the fault-pit of Pozega on the north and the Bacindol area on the southwest.

East of Pleternica, at the eastern end of the Pozega mountains, the trough of the Orljava valley runs between Pozega and the Dilj mountains. On the outcropping Leitha limestone at Pleternica the very high gravity of +31.9 mgal was observed. The gravity sinks from here towards the east and reaches its lowest value of +21.05 mgal 4 kilometers east of Pleternica. At that station the middle Pannonian crops out to the surface. From there the values rise towards the Dilj mountains on the east. Towards the south they sink along the Orljava Valley until they reach the Sava syncline. Only to the north, where measurements are incomplete or missing, is the relation with the Pozega fault-pit not entirely cleared up.

(N) The Pozega Fault-Pit (Profiles 69-71).

Even topographically, the depression in the Slavonian mountain terrain north of Pozega is a highly characteristic feature. The depression is framed in by mountains. On the west lie the Psunj mountains (984 meters), on the north the Papuk (886 meters), and Krdnja mountains (598 meters), and on the south the Pozega (616 meters) and Dilj (459 meters) mountains. Only towards the east did there remain, according to views hitherto current, a connection east of Kutjevo with the East Slavonian Lowlands in the direction of Djakova. Even though the greater part of the depression is covered by loess loam, there could be no doubt, according to the geological surveys up to the present, that it was a tertiary trough. Leitha limestone crops out on the northwest edge of the trough, between Orljavac and Velika. A gravimeter station on this limestone, near Orljavac, observed the high gravity value of +32.85 mgal. From here on the traverse was carried into the crystalline formations of the Psunj mountains for some distance to the northwest. (Profile 69.) Three stations located according to the geological map on gneisses and amphibolite schist gave values around +38 mgal. The absence of any gravitational gradient inside this area of crystalline rock is worthy of attention, as is the similarity with the gravity values observed on amphibolite schist at the southern edge of the Psunj mountains, near Sumetlica. (See page 92.) The northwestern station of this profile, with +38.8 mgal, near Kamensko, is even located once more on Leitha limestone, and the high gravity is naturally due to the crystalline schist that would be expected directly to underlie the limestone. From Orljava towards the southeast, Pannonian is imposed on the Miocene, and at the same time the gravity sinks until the minimum of +14.2 mgal at Skenderovci is reached (Profile 71). The sharp bend in the gravity curve at the edge of the crystalline rocks is here about almost more distinctly expressed than on the fringe of the Moslavina mountains. Although there is a rather high gravity difference of 18.75 mgal from the Leitha limestone near Orljavac down to the trough, the value of +14.2 mgal is still rather high for a minimum. It will be remembered in this connection that the gravity at the oil outcroppings of Ostri Vrh in the White Marl was only +1.5 mgal. It is, of course, true that the gravity conditions in the small, shut-off Pozega depression cannot be compared off-hand to those in the great, open Sava graben. But the conclusion still seems permissible that the thickness of the Tertiary even in the center of the Pozega fault-pit is not particularly high, and this would be an unfavorable omen for oil prospects. It is, moreover, uncertain whether the Sarmatian shales in this depression are developed as favorable source rocks.

The gravity rises towards all sides from the Skenderovci minimum. (Profiles 69-71.) It has already been pointed out that a very steep gravity slope immediately north of Pozega suggests the presence of a fault. In the northern part of the gravity trough the rise is more gradual. The northernmost and highest value of +31.9 mgal was observed on the road to Strazeman, at a point which is still 4.5 kilometers away from the outcropping crystallines, according to the geological map.

Towards the east the gravity also rises. (Profile 71.) In the transverse profile of the Jaksic-Vetovo road the lowest gravity is already +18.65 mgal, so that here the syncline

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has already lifted itself out to a certain extent. This shows up more clearly on the Nasice-Kutjevo sheet, further east, in the profile between Dijedina Rijaka and Gradiste. Here the lowest value is +26.95 mgal, and the isogams still continue to rise towards the east. There is little geological information about this region, and even the gravity surveys have only touched its edges. However, when he was remapping the Nasice-Kutjevo sheet between Pauoje and Podgorje, Doctor Poljak already found a large body of Leitha limestone, which points to the presence of basement rock near the surface of the southeastern spurs of the Krndja mountains. Further to the south the gravimeter observations near Imrijevci and Levanska Varos gave the very high values of +41.9 and +40.05 mgal. Even though the geological map we have mentioned shows only diluvium and Pannonian for these regions, it is entirely reasonable to conclude from the size of the gravity values alone that crystallines or late eruptives crop out here either at the surface or very near it.

The fault-pit of Pozega is thus completely closed on the east as well. The ancient mountains surround this depression not only on three sides, like a horseshoe, as has been hitherto assumed, but in the form of a ring closed on all sides.

(O) The Dilj Mountains (Profiles 72-73)

The Dilj mountains lie south of the highlands of

Imrijevci and Devanjska just mentioned. There are not outcroppings of crystalline on the surface here, and the large areas designated on the old geological outline maps as "hornfels trachyte" have contracted to a few small specks of andesite on Dr. Polyak's new map. The principal mass of the crest of the Dilj mountains is composed, on the surface, of White Marls, beneath which Leitha limestones come to the surface at the places of highest uplift. A gravity traverse was run across the ridge of the Dilj mountains, starting from Djedina Rijeka in the north. Thence via Glogovica it runs to Varos and then to the Sava near Brod. (Profile 72.) Near Djedina Rijeka +27.85 mgal was noted over outcropping Pannonian, presumably Valenciennes layers. This station lies in the southeast corner of the Pozega fault-pit. The gravity rises from there towards the ridge of the Dilj mountains on the south. The isogam at +30 mgal marks the approximate beginning of the White Marls; and the zone about 2 kilometers wide in which the gravity remains at this level coincides with the outcropping of the White Marls. (Profile 72.) The rise which then follows, up to +37.05 mgal near the Gavric mill, at the boundary between the Nasice-Kutjevo and Brod sheets, marks the occurrence of Leitha limestone at the core of the buried ridge of Dilj. For this, however, the values are unusually high - as high as on the outcropping amphibolite schist of the Psunj mountains. This suggests the occurrence of heavy masses of basement or eruptive rocks immediately beneath the Leitha limestone. There is then a sharp and persistent fall of the gravity from the mill towards the Sava lowlands: at a station at the edge of the Sava depression, 1.5 kilometers north of Varos and 6.5 kilometers south of the Gavric mill, +10.8 mgal is reached, corresponding to a gradient of about 4 mgal/km. In detail, this descent occurs as follows: the +32 mgal isogam is crossed at Glogovica, where the boundary between White Marls and Valenciennes layers is located by the new Janko geological survey; the +23 mgal isogam is at the boundary between Valenciennes and Rhombohedral layers, and the +12 mgal isogam at the boundary between the latter and the Paludinan layers, near Varos. It may be mentioned for comparison that this last boundary occurs at +18 mgal in the Gojlo structure.

Neumayr and Paul in their days located the Middle Paludinan layers in Varos itself, near the +10 mega-isogam. The gravimetric trough-axis of the Sava graben ~~is located~~ only lies 0.5 kilometers further to the south, at the southern exist from Varos, since the gravity trough has already risen so far strongly towards the east from its lower levels. The geological meaning of this is still not entirely clear. All we know is that according to Neumayr and Paul the topmost horizon of the Upper Paludinan beds is no longer present here, in this eastern region. This would seem to suggest that the thickness of the Tertiary system is no longer so great here as in the graben of Dolnji Bogicevci, and that this circumstance could perhaps have been unfavorable to the formation of oil deposits. Brod itself has a gravity of +10.9 mgal and already lies on the again ascending southern flank of the Sava graben.

(P) The Southwest Flank of the Dilj Mountains, with the Ks Kasonja Dome (Profiles 73-75)

The gravity conditions on the southwest flank of the Dilj mountains, west of the above-mentioned Djedina Rijeka-Brod profile, still remain to be discussed. Profile 73 runs about 6 kilometers further to the west, from Celikovic to Sibinj. Celikovic has +28.2 mgal, and is near the boundary between White Marls and Valenciennes Beds. The profile remains on the White Marls of the anticlinal arch of the Dilj ridge until reaching a point near Konj Brod. Over this stretch there is only an insignificant recession to +25.95 mgal. But then, in the 1800 meters to a station near the High Babina, the values fall to +13.95 mgal, which corresponds to the very high gradient of 6.7 mgal/km. This clustering of the isogams north of Sibinj strikes the attention even on the 1:200,000 outline map. According to Jenko's map, White Marls, Valenciennes beds and Rhomboidal beds crop out one after the other in this area, and in places the width of the Valenciennes outcroppings is only 100 meters. All this points to a steep flexure or, more probably to a strong faulting. The Rhomboidal Beds at Babina Glava dip towards Jenko with angles running from 16 degrees to

25 degrees. The gravity curve then flattens out further to the south: the reading of +8.45 mgal at Sibinj, 1700 meters away, corresponds to a gradient of 3.2 mgal/km. According to Neumayr and Paul, the highest Middle Paldinan and lowest Upper Paludinan beds crop out north of Sibinj. In contrast they found the lower division of the Middle Paludinan, with Paludina bifarcinata, at the southwestern end of Sibinj. Accordingly, the geological trough-axis of the Sava graben could very well pass through the central part of Sibinj itself, while the axis of the gravimetric depression passes 2 kilometers further to the south, with the gravity of +6 mgal.

Profile No 74, which is the next one on the west, runs from Prkljevci, in the Orijava Valley, over the pass-like graben between the main mass of the Dilj mountains and the uplift of Mount Kasonja jutting forward in the southwest near Grizici, to Andrijevci in the Sava valley. Northeast of the village of Prkljevci, according to Neumayr and Paul, sands and marlaceous clays of the rhomboidal beds lie directly upon the White Marls. The minimum of the Orijava Valley -- -17.8 mgal -- is close to Prkljevci. From here the gravity slowly rises towards the south-southeast, until the axis from the Dilj mountains to the Kasonja uplift is reached near Grizici at the station +19.2 mgal. Jenko locates this point in the Valenciennes beds, but a little further east the White Marls of the Dilj ridge emerge beneath it. For the next 1.5 kilometers the values

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decline only slowly to reach +17.8 mgal, while the Valenciennes beds continue to crop out on the surface. Only then does the gravity drop more steeply down to the Sava Valley: over the distance of 3 kilometers to a point 1 kilometer north of Slatinik, +6.3 mgal is reached. This gradient is accordingly 3.8 mgal/km and is thus not so steep as in the next profile 73 on the east, which we have discussed. On this section of the traverse, the Valenciennes and Rhomboidal beds crop out to the surface, and the Paludinan beds as well, covered only by diluvium. Only a short distance further to the south, the axis of the gravimetric depression of the Sava Valley passes, with a reading of +4 mgal.

A triangular mountain spur runs southwest~~ern~~ward from the Dilj mountains into the plain. It is bounded on the south by the Sava depression and on the northeast by the Orljava Valley. It is the small mountain formation of Kasonja (353 meters) to the north of Orijovac. While Neumayr and Paul had already found White Marls to occur at the core, the mapping by Jenko showed the presence of Leitha limestones besides the prevalent White Marls. It showed also that the entire formation constitutes a dome-like uplift, separated from the Dilj mountains by the Pass of Grizici with its outcropping Valenciennes beds. A gravity traverse was run over this uplift from Grizici to Orljovac via Lovcic. (Profile 75.) At first there is a strong drop over the 2.5 kilometers southwestward from +19.2 to

+10.55 mgal, corresponding to a gradient of 3.5 mgal/km. This section apparently is entirely in the Valenciennes beds. During the following kilometer the gravity then declines only to 8.25 mgal. Then follows a most extraordinary flattening out of the gravity curve. Over a distance of 5 kilometers the value sinks only to +4.95 mgal, corresponding to a gradient of 0.7 mgal/km. This section of the traverse crosses the top of the Kasenja dome, with Leitha limestone and White Marls in the core. This gravity profile is another fine example to illustrate the point that geological synclines may manifest themselves only by a flattening in the gravity curve. The center of the Kasenja dome has no significance for oil prospects, since it is too greatly elevated above the surrounding levels.

The low gravity of about +6 mgal on outcropping White Marl is also worth noticing. The +30 mgal observed on White Marls in the nearby Dilj mountains should be compared with this. The low gravity at Kasenja may probably be ascribed to the low regional gravity values in this part of the Sava graben and its edges, and perhaps also to especially great thickness of the White Marls here, and of the subjacent older Tertiary beds.

The gravity then falls more rapidly from the last-mentioned station of the traverse to reach -2 mgal at Orijovac. This section crosses the Pannonian and some of the

Paludinan beds. The classic occurrence of Middle and Upper Paludinan beds near Malino and Ciglenic, which Neumayr and Paul describe, is again reflected hereby the Streichende continuation of the -3 and -4 mgal isogams further to the west. Accompanying this the southwestward dip of the beds increases from 15 degrees to 65 degrees.

Two kilometers west southwest of Orijovac the trough-axis of the Sava graben is already reached, with a gravity of -5.5 mgal, forming a small local gravity-basin here, to the south of Orijovac. The gravity-trough here is particularly narrow, for immediately south of the axis the gravity commences a steep ascent towards the granite of the Motajica mountains near Kobas.

(B) The Region East of the Nasice-Brod Line

The region east of the Nasice-Brod line, i.e. about the area covered by State Concession II of Petroljej, Ltd., is with the exception of the environs of the Fruska gora, entirely located on the Slavonian plain between the Drava, Danube and Sava rivers, with elevations above sea level in the neighborhood of 100 meters. Extensive areas are swamp and floodlands. Accordingly, except for the edges of the Fruska gora and the hilly Brod area, information about the antediluvian formations is completely lacking. No oil seepages have been known to occur anywhere in the region. Gas showed occasionally near Erdut, Ilok and Vinkovci. No deep drilling has ever been done in the region. It could quite naturally be suspected that this region was a continuation of the deep Pannonian basin and was filled by Late Tertiary sediments of great thickness, and that it would perhaps reveal only few deep structures, possibly in the continuations of the Krndja and Dilja mountains and the Fruska gora. Such structures, if they existed, would then offer especially favorable conditions for the formation of major oil deposits.

But the picture disclosed by the gravimeter surveys of this region deviates sharply from these a priori considerations. To begin with, the general gravity level of the entire region proved surprisingly high. Large parts of it are above the +20 mgal isogam. And the gravity troughs between the highs are not as deep and do not go down to the same low levels as in the westerly lows of the Drava and Sava graben. The deepest minima of this region are between +5 and +10 mgal. The trough south of the Osijek structure does not even drop below +17 mgal.

In detail, the whole region is divided into a large number of highs and lows. But the gravity differences between the highs and lows are not so great as with the more significant structures further to the west, nor are the gradients so abrupt. If the gravity-profile tables of the western and eastern regions are compared, this becomes entirely clear. It appears that there is an upward regional trend of gravity towards the east in any case.

Thus, taking everything into account, the geological interpretation of the structures present here can be made only in the most rough and general way and subject only to strong reservations, the more so as the geological conditions in the Brod area and on the Fruska gora show that the facies of the Late Tertiary in this region is very strongly modified.

The whole area between the Drava and Sava grabens may be divided by two synclinal zones running west to east into three sections:

1. The structures along the lower Drava and the ~~Dabub~~ Danube;

2. The central chain of maxima;

3. The maxima on the northern fringe of the Sava graben.

(1) The Structures Along the Lower Drava and the Danube

(a) The Partial Maximum North of Nikojac Dolnji (Profile 76)

We have already pointed out that the Drava graben reaches an especially low gravity value near Moslavina on the Drava, with -6 mgal. From here eastward the trough axis ascends rather rapidly and crosses the Drava and the Hungarian frontier near Sv. Gjuraj. North of this point, which represents the easternmost portion of the Drava depression on Croatian territory, there is a fairly rapid increase in gravity to reach +9 mgal at the Drava river. This may be the southern slope of a structure located in Hungarian territory. This area is only 10 kilometers of the Vilanyi mountains in Hungary, which are about 25 kilometers long, trend from east to west, and are composed of Trua Triassic, Jurassic and Lower Chalk formations. Continuation surveys in Hungary would be required to attain any understanding of the structure which may possibly exist at Miholjac Dolnji.

(B) The Deep Gravity-Contour Ledge of Crnkovci (Profiles 77-79)

The rectangular gravity-contour ledge of Crnkovci lies to the south of the above mentioned easternmost Croatian portion of the Sava graben on Croatian territory. This ledge is a formation of only slight gravimetric relief. The +7 mega-isogam surrounds the high at right-angles on three sides, to the north, west and south, while there is probably a connection to the stronger high on Hungarian soil, which in turn is connected with the Valpovo high, to be discussed later.

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A few small local highs are superimposed upon the axis, and these are surrounded by closed +8 mega-isogams. There is a substantial gravity drop from the ledge only to the northeast toward a point near Moslavina and the Drava graben; (Profile 77). Towards the north the gravity drops by only 4 mgal over a distance of 4 kilometers, or a gradient of 1 mgal/km (Profile 78) and towards the shallow trough of Bocanjevci on the southeast, the drop is 3.5 mgal, or a gradient of 0.5 mgal/km (Profile 79).

There is only a very gradual decline of 1.5 mgal towards the southwest, from which a steeper climb begins to the Benicanci high, which we have discussed in an earlier section (Profile 78). Now it is true that even indistinctly expressed gravity structures, like those of Gojlo and near Recetari, have been shown to possess possible significance for oil exploration. But on the whole this gravity ledge of Crnkovci seems to be gravimetrically so very blurred as to discourage, for the time being at any rate, the hopes that might be raised by geophysical considerations; so that more detailed study of this area could only be recommended if oil were discovered in the region.

(C) The Partial Structure of Valpovo (Profile 80)

Northeast of Valpovo which has +8.6 mgal, there is a stronger rise in gravity towards the Drava. The highest value of +14.6 mgal was noted on that river itself. The gradient from Valpovo is 1.2 mgal/km. Understanding of this structure would be possible only on the basis of surveys north of the Drava on Hungarian soil. We have pointed out above that there is a possible connection between the gravity ledge of Crnkovci and the more substantial Valpovo high. A connection with the so-called Ban (Banat ?) mountains in Hungary is similarly not improbable. These mountains begin near Beli Monastir, 13 kilometers northeast of the Valpovo structure, and runs from southwest to northeast, so that the Valpovo structure lies in fact on the southwestern prolongation of the Ban mountains. Miocene marine marls and sandstones, traversed by basalt corridors, occur in these mountains.

(D) The Gravity Spur of Brodjanci-Bizovac

A distinct gravity spur, striking from southeast to northwest, appears on the gravity-slope south of the Valpovo structure and west of the Osijek structure, which structure will be discussed below. The axis of this spur commences near Solco pusta, 6 kilometers east of Brodjanci, with its highest value of +16.85 mgal, and runs northwestward for 10 kilometers via Bizovac, during which the gravity gradually falls off to +9 mgal between the +16 and +17 mega-isogams. Although this structure at first seems only faintly defined, it is still possible for it to attain a certain significance on account of its relatively deep attitude, if by any chance the

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neighboring Osijek structure, with its maximum value of +24.5 mgal, should prove to be too far elevated gravimetrically.

(E) The Osijek Structure (Profiles 81-82)

Along the Drava River, further to the southeast, the gravity at first sinks with considerable speed to reach a minimum of +8 mgal near Nard, about 4.5 kilometers southeast of the Valpovo maximum. From there to the Osijek structire the gravity rises again, slowly at first to Retfala, with +17.9 mgal, and then more steeply in the area of the Osijek structure proper until the maximum of +24.5 mgal is reached in the lower city of Osijek (Profile 82). Over this latter course of 6 kilometers, the gravity thus rises by 6.6 mgal, corresponding to the moderate gradient of 1.1 mgal/km. The gradient on the other sides of the structure are comparable. Towards the Jovanovac trough, 4.5 kilometers to the south, the gravity falls from the +24 mgal isogam to that of +18 mgal, corresponding to a gradient of 1.3 mgal/km (Profile 81). The axis of the Jovanovac trough runs along the rather high value of +16.4 mgal, and at a somewhat higher gravity level the trough-axis towards the east, near Sarvas, runs along the +17 mgal value. Nevertheless the I Osijek structure is clearly bounded by on the northwest, west, south and east by these troughs. Only to the north, on Hungarian soil, has the delimitation of the structure not been explored. However, the course traced by the isogams on Croatian territory makes it rather probable that the structure is also closed on the north. The Tertiary hill-country of the Ban mountains does not begin for another 25 kilometers to the north, so that in any case there would be enough room for a trough between these mountains and the Osijek structure.

If we compare the highest gravity values of the Osijek maximum with those of the West Croatian maximums, we find a comparable gravity at Grubisnopolje, where +25.4 mgal was noted, and the crystalline basement reached a depth of 1029 meters. Naturally this experience cannot be legitimately applied schematically to conditions here, so far away. But the seismic observations on the neighboring structure of Vera may perhaps furnish a somewhat better starting point, at least for the time being. According to these, the depth of the presumably Mesozoic basement may be estimated at 125 around 1250 meters, in the center of structure, with a gravity of +26.5 mgal.

On the whole, the gravity relief of the Osijek structure is not very sharp. The gravity differences with respect to the adjoining troughs on the south and east are only 7 to 8 mgal, with corresponding gradients of 1.1 to 1.3 mgal/km. Most of the structures in the western regions are more sharply defined. It should, for instance, be compared with the Rascani structure, near Krizevci (Profiles 27-28).

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The high of the Osijek structure inside the +24 mgal isogam is about 3 kilometers long and 2 kilometers wide.

All that is known about the subsurface geology of Osijek is from the old well-drillings. The diluvium, mainly composed of sand, reaches down to about 50 meters. Below that, to a depth of at least 300 meters, argillaceous sands alternate with clays, both of which presumably belong in the zone of the Paludinan beds.

(F) The Vera-Erdut Structure (Profiles 83-86)

There are various gravity-structures below the confluence of the Drava and Danube rivers, situated along the course of these rivers. Those structures -- those of Erdut, Vera and Vakovar -- continue on into Hungary, into the Backa area and apparently all belong to a large-scale gravitational massif. We shall first discuss the first two of these, which are both enclosed within the same concetric +18 to +24 mgal isogams, and form a single unit.

The Vera structure is mostly on Croatian territory. It trends from east to west and is envloped by the +26 mgal isogam. Its highest value is around +26.7 mgal. Towards the Brsadin trough on the south the gravity falls to +17.5 mgal (Profile 83). Towards the Jovanovac trough on the west it falls to +16.2 mgal (Profile 85). Towards the northwest Sarvas trough on the northwest it falls to +17 mgal (Profile 84). In

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contrast, there is only a slight drop to +24.6 mgal on the northeast, and from here it rises again to the Erdut structure. (Profile 86.) Ghe gradients on the flanks are moderate, 1.2 mgal/km on the west flank, for instance, with comparable gradients on the other flanks. Only towards the Erdut structure on the northeast is the gradient still lower, so as to leave a space 2.5 kilometers wide betwen the +26 and +25 mgal isogams (Profile 86).

The seismic profile furnishes a few points of departure for the geological interpretation of this structure. The results of the refraction shooting were entered below the respective gravity profiles (Profile 83). Five sedimentary complex were found, with respective wave velocities of 1800, 2100, 2400, 3350 and 5400 m/sec. Of these the upper sedimentary complexes form a flat arched uplift, with axis approximately coinciding with the gravity-axis. The upper edge of the deepest layer runs horizontally through the center of the structure at a depth of 1250 meters, while the axis of the seismic seems to be displaced towards the south by 1.5 kilometers with respect to the gravimetric structure. There is then a rather considerable drop towards the S, down to the 1500 meters depth level. On the contrary, there is only an insignificant drop of about 60 meters towards the N, which to some extent agrees with the lower gravitational gradients of the N flank. But while the gravity then continues to fall off slowly, the marking horizon even rises a little, obviously towards the Erdut structure. As for the interpretation of the deep seismic stratum, the most probable hypothesis is that it is a particularly compact mesozoic limestone. Crystalline rock is improbable because during the reflection shooting many good reflections were obtained down to depths 1000 meters below the seismic deep stratum.

For the time being no more precise interpretation can be given concerning the seismic horizons -- probably Tertiary -- which were found at the upper levels. Miocene beds of greater thickness appear to be intercalated at lower levels of the S flank. The Erdut structure lies in the great loop of the Danube, NE of the Vera structure and only indistinctly demarcated from it. The former strikes from NW towards SE and crosses over into Hungarian territory. The highest gravity found is +25.4 mgal. It falls towards the W along a common slope with the Vera structure towards the Sarvas trough; (17 +17.4 +17 mgal, Profile 84). But the E slope can also be clearly observed in the Danube loop, where the lowest observed gravity is still +20.9 mgal (Profile 84).

Gas has occasionally shown at Erdut. It will only be possible to form a precise opinion about the geological and oil exploration significance of the Vera-Erdut high when an exploratory well has been sunk there or on the neighboring structure of Osijek.

(G) The Partial Structure of Vukovar (Profiles 87-88)

The Vukovar high, which follows next as we descend the Danube, appears still higher and still more sharply defined. Most of this structure, again, lies on Hungarian soil. +31.3 mgal is the highest gravity observed here, while there are four other values over +30 mgal. The W flank trends due N and S, and the S flank due E and W, so that the isogams cluster together almost at right angles at the SW edge of the structure. The +20 to +24 mgal isogams envelop in common the three structures of Erdut, Vera and Vukovar, thus showing that all three belong to a larger gravitational mass. The Vukovar structure drops toward the Brsadin trough on the W (+16 mgal); towards the Borak trough on the S (+14 mgal); see Profile 88. In both cases the descent is rather abrupt, with a gradient of 2 mgal/km. The gravity-pass of Petrovci lies at +19.5 mgal between the Brsadin and Borak troughs. The SW edge of the Vukovar structure slopes towards this gravity-pass (Profile 87).

The high value of the maximum gravity, at +31.3 mgal, suggests that the basement of the Tertiary may not be far from the surface at this point. If it were desired to apply the lessons learned in the Moslavina mountains to the situation here, it could be assumed that more ancient rocks crop out directly below the diluvium. More precise conclusions result from a comparison of the neighboring structures of the Fruska gora and those of Vera. A maximum value of +37.15 mgal was observed at Sid, near the Fruska Gora, and this station is probably still 1 to 2 kilometers away from the outcropping crystallines. According to the seismic observations, the mesozoic basement near Vera lay at a depth of 1250 meters, with a gravity anomaly of +26.7 mgal. To go by this data, the basement of the Tertiary at Vera might be thought to lie at a depth of about 700 meters, or so near the surface that the prospects of oil are not very promising.

(2) The Central Chain of Maxima

(A) The Dakovo massif, with its isolated structures of Gorjani, Sirokopolje, Selci, Srzovic and Jarmina, together with the gravity-spur projecting towards Kladovac (Profiles 89-93)

The Pozega mountains do not end in the E at their topographic edge W of Dakovo, but instead project still further eastward as a great, heavy, subsurface mass stretching all the way to Vinkovci. The S boundary of this Dakovo mass is a gravity precipice striking from W to E and running from Trnava via Mikanovci to Vinkovci. This represents the E continuation of the N flank of the Sava graben in the Brod area. South of Dakovo this precipice drops from the +36 mgal. to the +14 mgal. isogam over a distance of 8 kilometers, corresponding to the fairly high gradient of 2.8 mgal./km. (Profile 91). The steepest gradient prevails in the central part of the gravity-slope. Conditions are similar further to the E near Mikanovci, where the gravity falls from +31 to +11 mgal. over the same distance of 8 kilometers, corresponding in this case to a gradient of 2.5 mgal./km. (Profile 92). Here the steepest gradient of 4 mgal./km. rules between the +30 and +20 mgal. isogams. The NE boundary of the Dakovo gravity-massif is formed by a bow-shaped cluster of isogams running from the region N of Brasevci to Vinkovci via Vuka, Koprivna and Markusica. On this N slope there is at first, NE of Brasevci, also a steep gravitational declivity, with gravity falling from +41 to +24 mgal. over a distance of 5.5 k., giving a gradient of 3 degrees 3.5 mgal./km. (Profile 91). But from this point further to the E the isogams pull apart more and more, so that NW of Vinkovci only a weak gravitational gradient still remains.

The whole gravitational mass of Dakovo is roughly encircled by the +26 mgal. isogams. The highest values are in the W: +49.3 mgal. was observed 3 kilometers S of Slatinik, +41.2 mgal. near Gorjani and +36.05 mgal. near Dakovo. It is remarkable that S the S boundary of the gravity-mass of Dakovo is marked in the terrain by a clear-cut topographical terrace formation running from Dakovo to Vinkovci via Old Mikanovci and Ivankovo. There is an area of loess N of the terrace, while to the S of the terrace forests and swamps stretch at elevations

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of 80 to 85 meters above sea-level. (See topographic map, Dakovo and Vinkovci, 1:75,000.)

A series of round highs, gravity-highs, mostly with not particularly sharp relief, is imposed on the gravity-massif of Dakovo: the Gorjani high, with +41.9 mgal. (Profiles 89 and 91); the Sirokopolje high, with 33.8 mgal. (Profiles 89 and 92) with the spur towards Korpiva Koprivna with +28 mgal.; the Selci high W of Dakovo with 36.05 mgal.; the Mrzovic high with 33.8 mgal.; and, finally, the Jarmina high with +27.4 mgal. (Profiles 89 and 93).

Nothing is known of the geology of the entire region beneath the diluvium. To judge by the experience in the Psunj-Papuk and Krndja mountains, further to the W, it may be regarded as extremely likely that, at least in the W section of the region, i.e. near Slatinik, Dakovo and Gorjani, where the gravity values go beyond the +35 mgal. isogam, the basement crops out immediately beneath the diluvium, a fact which has been hitherto entirely unknown. In the other eastern parts of the region as well, the gravity values are still so high that the thickness of the Tertiary system is probably insufficient for the formation of oil deposits. For this reason these structures have not been separately discussed here; but their gravimetric shape can be seen from the Profiles 89-93. For instance, the shallow trough between the Sirokopolje and Mrzovic maxima (Profile 90)

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recalls the gravity-trough on the N edge of the Prosara mountains, which we shall discuss later, (Profile 121), and which is to be ascribed only to petrographic differences within the crystalline formations.

Only at the easternmost end of the structures -- that of Jarmina (Profiles 89 and 39) -- could there be perhaps some prospect of oil. The maximum is here at +27.3 mgal. and is enveloped by the +27 mgal. isogam. In comparison with the Vera structure, which lies about 20 kilometers further to the NE, the depth of the pre-Tertiary basement may here be assumed to be about 1100 meters. The Jarmina structure is more sharply expressed than that further to the W on the Dakovo massif, since it lies inside the angle of contact between the S and the NE flanks of the massif. From the +26 mgal. isogam over the 7 kilometers to the Cerna trough on the S the gravity drops to the +11 mgal. isogam, corresponding to a gradient of 2.1 mgal./km. (Profile 93). The gravity falls to +18.4 mgal. at the Korod Nustar trough on the NE with a gradient of 1 mgal./km. The Jarmina axis sinks to +20.1 mgal. at the gravity-pass in the SE. Only towards the west is the gravimetric demarcation indistinct, since the gravity falls here only to +26.8 mgal. at the Mrzovic structure (Profile 89).

Finally, we must still point out the gravity-spur towards Kladovac. This spur projects southward from the center of the S flank of the Dakovo massif, S of Mikanovci, and ends at the gravity-pass of Kladovo, S of which the gravity once more climbs to the Zupanja high, while to the E and W respectively it falls to +9.6 mgal. at the Cerna trough and +7.4 mgal. at the Velika Kopanica trough. In the gravity-spur towards Kladovac, the isogams separate mainly between the +18 and +17 mgal. isogams, where a moderate thickness of the Tertiary System may be postulated. But it is really only the SE flank, facing the Cerna trough, which is more sharply defined, while the SW flank facing the Velika Kopanica trough only shows a feeble gradient, amounting to about 0.8 mgal./km.

(B) The Mirkovci Structure (Profiles 94-95)

The gravity climbs again SE of the gravity-pass of Vinkovci the gravity increases slightly again to reach the Mirkovci structure, whose maximum lies around +23 mgal. The Mirkovci structure forms an intermediate link between the Dakovo massif and the Fruska Gora. Accordingly the structure strikes from NW to SE. While in the NW there is a connection with the Jarmina structure and thus with the Dakovo massif, via the gravity-pass of Vinkovci (+20.1 mgal.); there is also a connection in the SE, via the gravity-pass of Djeletovci (+18.05 mgal.) with the gravity-spur of the Fruska Gora near Sidski Banovci (Profile 94). Similarly there is a connection in the N over the gravity-pass of Petrovci (+20 mgal.) with the

Vukovar structure. The gravity drop is steepest towards the Cerna trough in the SW, where the value falls from +23 to +13 mgal. over a distance of 4 kilometers, corresponding to the fairly strong gradient of 2.5 mgal./km. Towards the Nustar trough on the N, with +16 mgal., and the Berak trough on the E, with +14 mgal., both total fall and gradient is slight. The long and narrow gravity-ledge via Djeletovci to Fruska Gora is also worth noticing; it recalls the gravity-dike of Janjalipa, between Bujavica and Gojlo.

On the basis of the seismic observations at Vera, the basement at the Mirkovci structure may be thought to lie at a depth of about 1600 meters. In view of this fact, of the show of gas at Vinkovci and the gravimetrically well-delineated structure-form, the Mirkovci structure, including the gravity-dike via Djeletovci, may well be considered one of the most interesting objects of investigation E of Dakovo. It must, however, be kept in mind that the center of the structure has hitherto only been surveyed with widely spaced stations.

(C) The W Slope of the Fruska Gora (Profiles 96-99)

After an interruption of about 90 kilometers to the E of the last known outcropping of crystalline basement rock in the Krndja mountains, this rock emerges once more in the Fruska Gora, E of Sid, out of the diluvium of the East

Slavonian Plain. We have in this case a domal uplift of older rock, similar to an anticline, about 80 kilometers long and striking from E to W, which has been enveloped on all sides by Tertiary formations. The Tertiary commences in the SE near Vrtnik with the Oligocene, carboniferous Sotzka beds, which have been strongly dislocated by tectonic action. In the N and S of the mountains, Leitha limestone overlies it. This limestone, which, however, mostly rests immediately upon the basement rock, often dips steeply away from the mountains at angles which may reach 60 degrees to 80 degrees, thus showing its steep upwarping. We shall not go into the question whether the zone of Leitha limestone really does interrupt the central zone of the Fruska Gora near Gjipsa "for the most part under the cover of loess", as A. Koch puts it. In general the N zone of the Leitha limestone is much wider than the S zone, which allows us to conclude that the S flank dips more steeply.

In places, especially on the northern edge, Sarmatian limestones and marks, with characteristic fauna, overlie the Leitha limestone. The literature does not report any bituminous shales. A. Koch thought that he had observed a strong discordance between the Sarmatian and the Sub-Pannonian Marls.

The cement-marls of Becoin follow the Sarmatian, and represent the original type which served as the point of

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departure for the concept of the "Valenciennes layers". But it is obvious that they are mostly older than the "Valenciennes layers" of the Ilova-Drava region. Paradacna abichi and Valenciennesia reussi are missing from the Beocin marls, but in their place there are primitive Valenciennesia forms, such as V. pancici, V. Kiseljaki and Velutinopsis velutina. The rock is an unstratified, chalk-like lime-marl, and is at least 60 meters in thickness.

About 20 meters of "yellowish-gray sandy-muddy marl depositions" of the rhomboidal layers is said to be deposited directly above this at Beocin.

Then follow clays and sands of the Paludinan beds, together with lignite measures. Apparently the formations involved are Lower and Middle Paludinan.

The information available on the Late Tertiary formations is obviously scanty on account of the heavy loess cover. Oil geology considers it important that up to now no Sarmatian layers are known which could serve as source rocks and that the Valenciennesia layers do not appear to occur in the same facies as favorable reservoir rock, as is usually the case in petroliferous areas. It might, however, be possible that conditions were more favorable on the flanks of the Fruska Gora in the direction of the grabens.

Gravimeter surveys were made only of the plunging W axis of the Fruska Gora, since further surveys of the region had to be abandoned on account of the increasing partisan activity. +37.1 mgal. was the highest value, and was observed in the village of Sid. Outcropping crystalline schist is known to exist near the village of Sot, about 8 kilometers NE of here, but it is very probable that this schist extends under the loess as far as the topographic edge of the heights near Berkasovo, 2 kilometers NE of Sid. The station +37.1 mgal. is about 1.5 kilometers S of the prolongation of the principal axis of the Fruska Gora mountains. This axis, which plunges to the W, was then detected by the gravimeter observations (Profile 96), but right here the gravimeter stations are spaced rather far apart. According to Dr. Schmidlin's sketch of the isogams, there is at first the rather high gravitational gradient of about 2 mgal./km. between the +35 and +30 isogams, but then, between the +30 mgal. isogam at Nijemci and the +26 mgal. isogam at Sid, the gradient falls to only 0.7 mgal./km. This region could perhaps be re-examined at some later date, but the gravity values are still fairly high. From the +26 mgal. isogam down to the station +18.2 mgal. at the gravity-pass of Nijemci, the steeper gradient of 1.6 mgal./km. rules once more.

Two individual features then stand out on the NW end of the plunging axis of Fruska Gora: the shallowing of the gravity contours E of Sidski Banovci and the lateral gravity axis running SW of this locality to the gravity-ledge of Djeletovaci-Mirkovci. The +22 and +23 mgal. isogams separate it to the E of Sidski Banovci, between the Fruska Gora high and the gravity-pit of Berak, and run at a distance of 2.5 kilometers apart. SW of that village a lateral axis diverges in the area of the +19, +20 and +31 isogams, and then follows the same course as the Djeletovci-Mirkovci gravity-ledge (Profile 97). The gravity level of both these suggested structures would not be unfavorable.

A traverse was also run over the S flank of the Fruska Gora massif from Sid to Morovic (Profile 98). The gravity here sinks by 21 mgal. over a distance of 9 kilometers from +37 to +16 mgal., giving a gradient of 2.3 mgal./km. Gravity-precipices of comparable steepness are found in only few places E of Nasice and Brod. (Mrzovic, Vukovar.) The synclinal axis of the E Sava graben is almost reached by the +16 mgal. isogam. That axis is S of Morovic at about +13.5 mgal.

Indications of a weak lateral axis trending S at a level between the +15 and +17 mgal. isogams were noted E of Morovic.

The E traverse ran from Sid SE to Kuzmin via Kukujevci; thus it was crossed the gravity-slope obliquely. At Kukujevci the gravity was +24 mgal. and at Kuzmin it was

+14 mgal. The synclinal axis of the Sava syncline runs S of Kuzmin near +9 mgal. It has thus sunk to a lower gravity-level further to the E of Morovic, and probably sinks still more in the unsurveyed area still further E, presumably linking up ultimately with the deep Sovkerin syncline in the Banat, N of Belgrade. Probably therefore there is again a particularly deep section of the Sava graben bordering the central and easterly portions of the Fruska Gora. This improves the general prospects of this region, which has not yet been gravimetrically explored, and to which the Serbian part of the concession S of Mitrovica belongs.

(3) The Maximum on the N Fringe of the Sava Graben

(a) The Tomica Anticline Near Brod (Profile 100)

Neumayr and Paul already found indications in lignite mines that the Dilj mountains were bordered by a Late Tertiary anticline N of Tomica, 5 kilometers N of Brod. According to them, sands of the Rhomboidal level crop out at the core of the anticlinal crest, while the flanks are formed by lignitiferous Lower Paludinan beds. Further to the N the layers emerge again on the S slope of the Dilj; and accordingly they found sands of the Rhomboidal horizon, dipping slightly to the S, on the ridge between the Kindrevo and Orijovac valleys. The Tomica anticline recalls that of Gojlo by its general geological position as well as the degree of its uplift.

A gravity traverse was run along the Gabric Mill-Poderkavje-Rastusje-Tomica, and passes over the presumed W end of the Tomica anticline. As mentioned on page 104, +37.05 was noted on the Leitha limestone at the Gabric Mill. Over a distance of 3 kilometers from here, perpendicular to the trend (of the anticline ??) the gravity drops to +26.25 mgal. at the boundary near Poderkavje between Valenciennesia and Rhomboidal beds, giving the high gradient of 3.6 mgal./km. In the Rhomboidal beds, the gravity then plummets down to +17 mgal. in 2.1 kilometers, making the gradient here actually reach the level of 4.4 mgal./km. The values continue to drop along the probable line of the W end of the Tomica anticline to reach +12.3 mgal. at the mill S of Tomica, so that the gradient even here still is 3.1 mgal./km. Thus while both the Gojlo and Resetari structures are marked by a distinct shallowing in the gravity contours at those portions of the gravimeter profiles that pass their respective ends, nothing of a similar nature can be observed here from the present data. It must also be considered in this connection that the axis of the Sava graben is already reached 1 kilometer S of the Tomica mill, at the relatively high gravity of +9 mgal., so that Brod with its +10.9 mgal. lies on the S flank of the graben. In contrast, the axis of the Sava syncline, opposite the Gojlo structure, is at +2 mgal. In spite of this the Tomica anticline warrants more

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detailed geological study and possibly also further geophysical surveys, in view of the fact that bituminous shales occur in the Sarmatian formations of the Dilj mountains, that there springs charged with H_2S in the environs, for instance N of Kindrovo, and that there are favorable reservoir rock formations, at least in the Rhomboidal layers.

(B) The Trnjani-Staro Topolje Shallowing of the Gravity Contours (Profiles 101-102)

A number of distinct shallowings in the gravity contours were noted in the Trnjani-Staro Topolje area, about 8.5 kilometers E of the Tomica anticline. These are perhaps of significance to oil geology. The first of them lies in the Sava plain N of Trnjani. If we follow the traverse profile down from the Dilj mountains (Profile 101) we see that the gravity falls at first from +27 to +21 mgal. in 4 kilometers, giving a gradient of 1.5 mgal./km. Then follows the clear-cut shallowing of Trnjani, so that the +20 mgal. isogam is only crossed after a distance of 2.5 kilometers. The deepest part of the trough is then reached at +14.55 mgal. after a further 3.5 kilometers, giving a gradient of 1.7 mgal./km. again. The high gravity at the synclinal axis is due to its nearby intersection by the gravity-pass of Bicko Selo, with +17.6 mgal.

There is a slight decline by 1 or 2 mgal. E of the Trnjani shallowing, followed by the reappearance of more extensive shallowings in the area N of Bicko Selo and near Staro Topolje (Profile 102). These shallowings are all within the +17 and +19 isogams. The W section N of Bicko Selo appears to strike N and S and to be connected to the Bicko Selo gravity-pass.

There is even a small closed maximum in the E section, near Staro Topolje. Another gravimeter traverse was run from Trnava N and S along the S slope of the Dilj mountains. +27.9 mgal. was noted near Trnava, near which, according to Dr. Poljak, Rhomboidal layers crop out. From here the gravity drops in 5.5 kilometers to the small minimum of +16.08 mgal. near Novo Topolje, giving a gradient of 2 mgal./km. From there is a modest rise to the +17.7 mgal. maximum near Staro Topolje. The gravity then declines again to reach +13.9 mgal. near Oprisavci. Here lies the axis of the Velika Kopanica syncline which emerges toward the W and represents the continuation of the Sava graben E of the Bicko Selo gravity-pass. The Staro Topolje maximum seems to trend from E to W, and by its orientation with respect to the Bicko Selo gravity-pass as well as by its rather blurred definition it recalls the Osekovo structure near the gravity pass of Voloder.

It is possible that the gravity-contour shallowings of Trnjani, Bicko Selo and Staro Topolje all belong to a single unified structure striking from W to E, which would be about 10 kilometers long (Profile 102). This region deserves nevertheless to be kept in mind because of the relative proximity of the known oil showings and oil indications of the Brod area.

It may be noted, by way of afterthought, that NE of Trnava, on the edge of the Dilj mountains, there are indications of a gravimetric trough striking from NW to SE, and that the isogams veer towards the N in the very incompletely surveyed area between Andrijevci and Vrpolje, thus perhaps pointing to an anticlinal formation plunging towards the SE.

(C) The Zupanja-Vrbanja High (Profiles 103-110)

The surveys have shown the existence of a very considerable gravity-massif in the middle of the Sava depression in the area of the great Slavonian oak forest. This high is composed of two partial highs which are approximately at right angles to each other: the Zupanja high in the N, striking E and W, and the Vrbanja high in the S, striking N and S. Both highs have been surveyed only with widely space stations. The centers of both maxima remained undertermined by the observations, while the E flank of the Vrbanja high was not surveyed at all. Thus maximum values for both highs can be given only approximately: about +24.5 mgal. for the Zupanja high, and about +27.5 mgal. for that of Vrbanja. It cannot be determined from the available gravimetric data whether or not there is a small gravimetric subsidence between these two partial highs.

The entire gravity-massif is connected in the NE through the gravity-pass of Nijemci (+18.3 mgal.) with the Fruska Gora. From there to the gravity-pass of Kladovac, at +14.2 mgal., the N boundary of the massif is formed by the Cerna syncline with +9.6 mgal.

On the W it is bounded by the Sava graben, which makes two right-angle bends in this area, paralleling the course of the Zupanja-Vrbanja gravity-massif itself. The Velika Kopanica syncline runs N and S at first, until reaching Slatina, thence from W to E until reaching a point E of Vidovice, thence, according to incomplete surveys, running N and S to Brcko, thence along the Sava running once more W to E. Gravity values in the synclines range from +18 to +10 mgal. while near Brcko, where the observations have probably failed to hit the deepest parts of the syncline, they are lower than +12.6 mgal. The troughs surrounding the projection of the gravity-massif to the SE, at the confluence of the Drina, have not been located by the gravimeter survey. To the E, finally, the W end of the great syncline S of the Fruska Gora extends to the E edge of the massif in the area of Morovic and Lipovac, with a gravity of +15 mgal.

The W to E profile through the Zupanja massif (Profile 103) shows that at first the gradient only amounts to 0.7 mgal./km. from Babina Greda, in the Velika Kopanica syncline to the +20 mgal. isogam and from there to the high at the dome of the structure, it is only 0.2 mgal./km. The gradient is somewhat steeper on the E flank towards Lipovac: it is 1 mgal./km. between the +24 and +17 mgal. isogams. It is still a little steeper on the N flank towards the Cerna syncline, where it reaches 1.5 mgal./km. between the +22 and +13 mgal. isogams (Profile 108), and in the W section of the S flank, where it even reaches 2.7 mgal./km. between the +23 and +15 isogams. As a whole, however, the Zupanja structure shows a gravity pattern of fairly weak relief.

The structure divides into two branches at its W end. The N branch runs NW towards the gravity-pass of Kladovac, (+14.2 mgal.) (Profiles 104-105). It is possible that there is even a closed local structure within the +16 mgal. isogam here, near Banot Dol.

The S branch runs from Zupanja via Domaljevac to a point S of Babina Greda, so that the pronounced meanders of the Sava between Bosnian Samac and Zupanja lie right on its course (Profiles 106-107).

The moderate gradient of 1.5 mgal./km. rules on the S flank of the Urbanja massif between the +26 and +16 mgal. isogams, while on the W flank, between the +26 and +17 mgal. isogams, the gradient even reaches 3 mgal./km (Profile 109). This is the highest gradient in the entire gravity-massif of

Zupanja-Vrbanja, so that the isogams, which here trend N to S, are clustered together most closely in this section.

Two branches of the Vrbanja massif project to the S, but both of them were only sketchily surveyed. One of them runs SW and meets the Sava near Brcko (Profile 110). The other branch, which is longer, was only surveyed -- to some slight extent -- on its S flank. It runs ESE to the Sava river, at a point about 8 kilometers NE of Jamena, with gravity +21.75 mgal.

The striking southward bulge of the Sava between Zupanja and Brcko seems, topographically considered, to be related to a withdrawal away of that river away from the Zupanja-Vrbanja massif.

For the time being no clear idea of the structural geology of this massif can be formed. To go by the experience in the general area, especially the seismic surveys near Vera, the pre-Tertiary basement at the center of the Vrbanja structure could be provisionally located at a depth of around 1300 meters. The Bosnian Eocene mountains are close: the N edge of the Majevica mountains is about 30 kilometers to the S, and the E edge of the S Vuejk Vuejak mountains is about 35 kilometers to the W. Thus there is even a possibility of meeting Eocene formations in the basement of the Zupanja-Vrbanja high. The gravity pattern, however, warrants the assumption that this

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massif has a closer connection with the Fruska Gora, and also with the Dakovo massif, than it has with the Flysch mountains of Bosnia. It even seems, rather, that the Zupanja-Vrbanja massif is more likely to have formed the column against which the Bosnian Flysch mountains were folded. Still the relatively short distance of about 50 kilometers from Brcko to the oil seepage of Tuzla lends the Zupanja-Vrbanja massif at least a certain provisional interest for oil geology. This interest is somewhat enhanced by the hitherto unconfirmed reports of oil showings at Brcko itself, and by the position of the massif on the N fringe of the Sava graben, the same position occupied by the oil seepages of Staro Petrovo Selo and Bacindol, further upstream on the Sava.

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IV. THE LONJA-SAVA GRABEN

It was already clear from the topography of the terrain and the geological data available that the course of the Sava between the isolated Croatian mountain formations and the Bosnian mountains follows, on the whole, a zone of tertiary subsidence. The detailed course of the synclinal axis of this graben, its subdivision by transverse ledges, and the position of its deepest basins, however, were only revealed by the gravimeter surveys. These surveys also showed that the deep graben in the NW does not commence, as might have been supposed, in the broad low plains S of the Sljeme near Zagreb, but on the contrary, in the not very conspicuous valley of the upper Lonja S of the Kalnik mountains and E of the Sljeme.

(A) The Komin-Lojnica section of the upper Lonja Graben

In spite of the incompleteness of the survey in this section, it is still apparent that this graben originates suddenly on the S slope of the Kalnik mountains, to the S of Hum, and then runs from N to S at right angles to the trend of these mountains. On the W, this part of the graben is accompanied in the W by the steep E gravity-slope of the Zagreb Forest, and by the Rascani and Vrbovec structures in the E. Facing the latter structure the gravity in the graben sinks below the zero isogam. It is 60 km. further SE, at Novska, that such low values are first encountered again in the Sava graben. This section of the Sava graben is bounded on the S by the ledge projecting to the NW from Kriz-Sumecani-Ivanic Klostar, which ledge descends from the Sljeme to meet

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an axis a Zerjavinec-Prozorje axis coming in the opposite direction. Thus a gravity-pass at +6 mgal. is formed in the Precec area.

(B) The Bregi-Okoli Section of the Sava Graben.

This section runs from NW to SE between the gravity-pass of Precec and that of Gracenica, near Osekovo, still continuing to follow the general course of the Lonja, while the Sava itself flows SW of this line over the high of Martinska Ves. The lowest gravity values on this section are somewhat above +4 mgal. At an earlier date the Bregi well was sunk by Bitumen, Ltd. at +5.8 mgal., near the synclinal axis; but as a result of its geophysical trough position it produced no results, and was finally abandoned at in the Paludinan layers at a depth of 582 meters.

On the NE this section of the graben is accompanied by the I anic Klost r-Sumecani-Kriz s ructure and also, subsequently by the slope of the Losla ina mountains, with which it is in direct contact; on the SW by the Martinska Ves structure and on the S by the Preloscica-Osekovo structure. Two lateral synclines project W from the main syncline, one towards the Velika Gora, S of Zagreb, and the other towards the area N of Sisak. The closed pit-like minimum of the Velika Gorica syncline lies at +8.5 mgal. and thus not particularly deep, and the one N of Sisak is similarly situated at a gravity-level of +7mgal.

The SE end of this section is at the gravity-pass of Gracenica, near Osekovo, at +9.3 mgal. This gravity-pass is formed by the projection of the wide Proloscica structure into the Sava syncline.

(C) The Gracenica-Dolnji Bogicevci-Nova Gradiska-Orijovac-Brod Section of the Sava Graben

The deepest part of this section and thus of the whole Sava graben lies a little to the S of Okucani and Nova Gradiska. Here, between the Psunj mountains on the N and the Prosara and Kotajica mountains on the S, the gravity lies beneath the -10 mgal. isogam throughout an area striking exactly from E to S. -13.6 mgal. is the lowest value, and was noted at Dolnji Bogicevci. It may be assumed, judging by the results of the Seismic tests near Resetari and of the drilling of Resetari I, that the basement of the Tertiary is here at a depth of about 3200 m. The fact that this section is only 15 kilometers wide between the +10 mgal. isogams on the N and S should also receive proper attention. The Sava graben here has the character of a deeply subsided cleavage with precipitous marginal fractures, comparable to the Rhine Valley rift in SW Germany. Here likewise the Sava graben is deepest and most abrupt in precisely those areas where the uplift of the marginal mountains has been greatest.

From the gravity-pass of Gracenica on the NW, the Sava graben sinks gradually but steadily to this deepest section. On the NE it is accompanied at first by the

Moslavina mountains, then the Gojlo structure, the Medjuric-Janjalipa gravity-ledge and, finally, by the Kricke-Novska axis. The trend of this section from NW to SE is due to the stepped or set-back pattern of the advance of the Psunj mountains towards the Moslavina mountains on the S.

In precisely similar fashion the gravity then rises constantly and very sharply, E of Nova Gradiska. The synclinal axis passes Orijovac at -5 mgal., and Brod at +10 mgal. and finally attains the gravity pass of Bicko Selo at +17.5 mgal. which is thus at a higher gravity-level than the gravity passes of Precec and Gracenica, located further to the W. The gravity pass of Bicko Selo is formed by the meeting of one gravity ledge projecting southward from the Trnjani area with another gravity ledge projecting northward from the Vucjak mountains. This section of the Sava Graben is accompanied in the N by the Pozega and Dilj mountains, in the S by the Motajica and Vucjak mountains and the spur of the latter towards Zbijeg on the W. N of Orijovac, the Sava Graben is narrowed to a width of only 7 kilometers by the vaulting uplift of Rasonja.

<u>(B) The Velika Kopanica-Bosnian Samac-Bercko Section of the Sava Graben</u>

The synclinal axis sinks rather rapidly again to the E of the gravity-pass of Bicko Selo, continuing its W to E trend until it reaches Velika Kopanica, where the deepest lowest gravity of the syncline runs around +8 mgal. The syncline then, however, makes a perpendicular bend to the S and runs at about +8 mgal. to Slatina via Bosnian Samac. The N and E flanks of the Vucjak mountains to the SW meet similarly at right angles. This parallelism suggests a causal connection.

A plunging axis projects towards this section of the Sava graben from both the E and the W: the Zupanja-Domaljevac axis, coming from the Zupanja massif on the E, and the Vrbovac-Gornja Dubica axis, coming from the Vucjak mountains on the W.

The further course of the main synclinal axis beyond Slatina is not entirely clarified. It is true that there is one synclinal axis that runs ENE after undergoing still another right-angle bend, which axis bounds the S flank of the westerly part of the Zupanja massif. But this syncline then climbs up to a gravity-level of over +24 mgal. at the pass between the Zupanja and Vrbanja massifs, so that this branch syncline can scarcely be considered to be the continuation of the main Sava syncline.

The latter, on the contrary, probably runs SE from Slatina towards Brcko. Another minimum has been located E of Brcko, near Racinovci, by the incomplete surveys in that area. The axis of this minimum must run at a level lower than +12.6 mgal. There is thus probably a connection from Slatina down to here, which must run over a low gravity-ledge E of Zabar around the level of +17 mgal. The continuation of the main Sava graben should thus be sought here, in this only partially surveyed area.

(E) The Morovic-Kumin Section of the Sava Graben

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The most easterly gravimeter measurements S of the Fruska Gora located another section of the Sava graben on the Morovic-Kuzmin line. This section, too, runs from W to E and dips towards the E. On the synclinal axis at Morovic the gravity is +14.6 mgal., on the same axis at Kuzmin it is +8.9 mgal. Further to the W, the sincline then divides into two branches, both of which then rise strongly. One of them runs W on the gravity pass between the Zupanja and Vrbanja massifs (+24 mgal.) while the other runs NNW on the gravity-pass of Nijemci between the Fruska Gora and the Zupanja massif. (+18.5 mgal.). But the main syncline probably runs SW around the gravity-spur of Jamena to establish connection with the syncline E of Brecko.

We have already mentioned that the main Sava syncline probably runs E along the entire Fruska Gora chain, and that it probably makes a connection finally with the deep Betkerin syncline in the Banat.

The whole Lonja-Sava graben (or geosyncline) is about 320 kilometers long from Komin to Kuzmin, and to the Danube E of Semlin it is about 400 kilometers. The length of the Rhine Valley geosyncline -- 800 kilometers -- should be compared with this. There is a major difference with Lonja-Sava and Rhine Valley geosynclines, however, in that the former is only developed in some places as a true graben, while the main line of its development as rather as a geosyncline and that the folds on edges of the Sava geosyncline play a greater role than they do at the fringes of the Rhine valley geosyncline, where faults predominate. The curved shape of the whole syncline that parallels the Legrad-Sv. Djuraj section of the Sava geosyncline should also be duly noted.

Geophysics has thus proved that the consolidation of the Central Croatian gas and oil deposits showings into a single Sava Zone was entirely justified. In fact, the most important of these showings, from Ivanic Klostar through Kikleuska, the Gojlo structure, Bujavica, Paklenica, Bacindol, Resetari, up to Staro Petrovo Selo, all lie on the N fringe of this long minimum zone, while the gas showings of Sisak, Struzec and Osek Oskovo lie on its S edge. The occurrence of bituminous shales in the Sarmatian layers in the graben has been proved, all the way into the Brod area, while up to now no certain indications of oil have ever been found further to the E.

V. THE STRUCTURES W AND S OF THE LONJA-SAVA GEOSYNCLINE

(A) The E Slope of the Zagreb Forest. (Profiles 111-112)

In the area of Sv. Ivan Zelina the surveys extend almost to the E edge of the basement rock of the Zagreb Forest, here composed of Triassic formations. The most westerly observations, with +27.4 mgal., were at the approximate overhanging junction of the White Marls, under which the Leitha limestones crop out at the edge of the Zagreb Forest. (Profile 111) The N and S trend of the isogam clusters, paralleling the upper Lonja graben, is noteworthy, as is the strong and steep drop in gravity from the edge of the Zagreb Forest down to this graben near Komin. This drop amounts to 18.5 mgal., from +27.4 mgal. at Sv. Ivan Zelina to +8.9 mgal. at Komin. In the course of this descent the gravity falls in only 3 kilometers from the +26 to the +12 isogam, giving the strong gradient of 4.7 mgal./km. Accordingly the E edge of the Zagreb forest must have been formed by a sharp faulting disruption. In no case is there any connection between the Zagreb Forest and the Kalnik mountains, as was formerly suspected.

Further to the SW towards Zagreb, the gravity stations remained a good distance away from the transgression of the Tertiary formations onto the basement rock of the Sljeme. The highest values noted between Sv. Ivan Zelina and Zagreb ranged between +13 and +17 mgal., with all the stations remaining throughout in the domain of the Upper Rhomboidal beds. An almost horizontally plunging axis projects between Zerjavenec and Dugoselo towards the gravity-pass of Precec, and the incidental s a lowing of the contours between the +12 and +13 mgal. isogams is rather striking. (Profile 112) The subsequent decline of the axis is quite gradual. In 7 kilometers the gravity drops from the +12 mgal. isogam only as far as the +7 mgal. isogam, giving the weak gradient of 0.8 mgal./km.

The area surveyed to the W of this axis, as far as Zagreb, already belongs to the Velika Gorica syncline and has a very weak gravitational gradient. The axis of this syncline, at +8.5 mgal., lies at a relatively high gravity-level.

As far as oil prospects in general on the borders of the Zabreg Forest are concerned, the Sarmatian is developed in the form of bituminous shales at the edge of the forest, near Markusevac and Vrapce. The thickness of the Valenciennesian beds, between White Marls and Rhomboidal beds, is apparently slight and predominantly developed in argillaceous facies. However, further towards the interior of the syncline they may not improbably be developed in greater thickness and perhaps also with higher content of sand than at the very edge of the mountains. There would, therefore, appear to be some prospect of oil. Even though gravimeter surveys have also failed to show any particularly favorable structure within this area, the Zerjavinec-Dugoselo axis would still seem to be the most worthy of attention, since at least on the E it borders, not on the shallow syncline of Velika Gorica, but on the deeper geosyncline of the Lonja and Sava.

(B) The Structures S of Zagreb

(1) The Dubranec-Kravarsko Structure (Profiles 113-114)

The Dubranec-Kravarsko structure rises S of the Velika Gorica syncline to its maximum of +21.7 mgal. near Dubranec. (Profile 113) The total rise in gravity thus amounts to 13.2 mgal. Between the +10 and +21 mgal. the gradient -- 1.5 mgal./km. -- is fairly steep. The gradient on the NW, towards the Gradiscari syncline (+8.0 mgal.) is comparable. This syncline connects on the W, beyond a small gravity-pass, with the Velika Gorica syncline. Towards the small Hrusevac syncline on the S, with +13.3 mgal., there is a moderate decline amounting to 8.4 mgal.; but during this stretch the gradient between the +20 and +15 mgal. isogams reaches the high figure of 3.3 mgal./km., so that there is even a possibility of a fault disruption here, on the S edge of the Dubranec structure.

The structure is enveloped within the +18 mgal. isogam. Its E to W measurement at this level is 6 km. while its N to S extent is 6.5 km.

The structure projects towards Kravarsko on the SE. The projection is especially distinct in the +16 mgal. isogam. (Profile 114) The Kravarsko well was sunk at the edge of this projection, at +15.5 mgal., by Uljankik, Ltd. The projection then ends at a small gravity-pass, at +15.9 mgal., near the settlement of Sevaric. Beyond this point the gravity rises again towards the Kupa on the SE, where it finally attains +24.. mgal.

The exact profile of the Kravarsko well is not known. It was, however, certain that the well was spudded in Paludinan beds at the dome of a geologically located structure, that at least from a depth of 740 m. the drill encountered argillaceous Valenciennesia beds, and that, between 869 and 874 m., Leitha limestones, partly compact and partly of coarse sandy structure, were penetrated. According to this the Pannonian is only of slight thickness, and the Valenciennesia beds seem to have a low sand content. The shallow position of the Leitha limestone is striking. In Well 4 at Gojlo, for instance, sunk at +17 mgal., this formation was only encountered at a depth of 1160 m.; in Well I Grubisnopolje, at +24 mgal., it was found at 9?0 m., while in Well I Dujanica, at +14.5 mgal., its depth was ?13 m. The shallow depth of the Leitha limestone in the Kravarsko well, in spite of the relatively low gravity of +15.5 mgal., gives rise to the suspicion that there are Oligo-

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Miocene Lacustral formations of greater thickness between the Tortonian and the basement, the more so since the presence of Oligocene a short distance further S, at Lasinja, is already known from earlier mappings.

Geophysically the area of the closed structure near Dubranec, some 6 km. NW of Kravarsko, appears at first glance to have better prospects of oil. But the high gravity of +21.6 mgal. indicates that the basement is a few hundred meters nearer the surface than at Kravarsko. For comparison it may be noted that +30 mgal. has been noted at the SW corner of the Gradac survey area, on the edge of the small carboniferous massif of Lasinja. This shallow position of the basement rock, taken together with the apparent lack of reservoir rocks in the Valenciennesia beds, makes prospects of oil in the Kravarsko-Dubranec area rather slender.

(8) The Martinska Ves Structure. (Profiles 115-116)

From the Dubranec-Kravarsko structure the gravity sinks at first towards the NE. A shallowing, some 3 km. wide, then appears near Pescenica between the +13 and +12 isogams. A flat trough then follows a +10 to +11 mgal. and finally there is again an easy climb towards the Martinska Ves structure, which reaches a maximum value of +13.5 mgal., strikes from SE to NW, and is enclosed within the +12 and +13 isogams. The structure, within these confines, is 11 km. long and 4 km. wide . It lies entirely on the Sava plain; the Sava itself flows for a certain distance along its axis. The structure forms the SW flank of the Sava geosyncline exactly opposite the Kriz-

Sumecani-Ivanic Klostar structure. The relatively steepest gravity slope from this structure is also towards the Berg Bregi syncline on the NE, in the direction of the Sava geosyncline: here the gravity falls by 9.2 mgal. to reach a value of +4.4 mgal. (Profile 115) During this decline, the gradient on the middle part of the slope, between the +12 and +7 isogams, amounts to about 1.5 mgal./kilometers, which is thus not steep and in any case weaker than at Sumecani-Kriz on the other side of the Sava graben. (Compare Profiles 34-35.) The gradient toward the Streljecko syncline on the S. which is N of Sid Sisak, is comparable. (Profile 116) But the gradient towards the W and NW is very weak, for the total drop here is only 2-3 mgal. (Profile 115) On the whole the Martinska Ves structure is not one of very pronounced gravity-relief.

Geologically nothing is known about the nature of the Martinska Ves structure buried beneath the diluvium of the Sava lowlands. Certain conclusions, however, may be drawn from the conditions found at the neighboring structures of Kravarsko, Sisak and Sumecani.

	Gravity high in mgal.	Depth of boundary between Paludinan and rhomboidal in meters	Formations at bottom of well
Kravarsko	+15.5	about 200	Tortonian at 1000 meters
Well 4 at Sisak	+ 9.5	about 275	Valenciennesia at 1015 meters
Sumecani-Kriz	+14.25	50	----------
Martinska Ves	+13.55	---------	-----------

It may be assumed from these data that the Valenciennesian beds at Martinska Ves lie at a depth between 500 m. and 1000 m. and that the basement of the Tertiary is at about 1500. The development of the Valenciennesian beds in greater thickness and with high sand content at Sisak, only 12 km. away, and the occurrence of gas there, in spite of the absence of any real gravimetric structure, indicate that the Martinska Ves structure still has certain prospects. In particular, if exploration at the parallel structure of Sumecani-Kriz were to show favorable results, exploration of the Martinska Ves structure could then be approached in more detail. In that case preliminary exploration by shallow drilling would be desirable before sinking a deep discovery well.

(C) The Preloscica Gravity-Spur with its Secondary Structures

(1) The Preloscica Gravity-Spur. (Profiles 117-118)

A very considerable gravity-spur projects E from the Tertiary hill country S of Sisak into the Sava plain. It begins near Gornje Komarevo in the hill-country, with a gravity of +27.45 mgal., whence it descends via Preloscica (+20 mgal.) to Strusec-Osekovo (+10 mgal.) It has an axis plunging towards E, the existence of which is due to the fact that the isograms near the W section of the spur, E of Sisak, strike from WSW to ENE, while near its E section they strike from N to S. This massif sharply interrupts the Sava geosyncline and forms the gravity pass of Tracenice, which separates the Bregi-Okoli section of that geosyncline from the Dolnji-Bogicevci-Nova Gradiska section. The spur is bounded on the N by the S fringe of this Bregi-Okoli section and by the lateral syncline near Streljecko, N of Sisak. During the 12 km. between Gornje Komarovo and Streljecko, the gravity falls by 20 mgal. from +27.45 to +7 mgal., while the very considerable gradient of 2.5 mgal./km. rules between the +10 and +25 mgal. isogams. (Profile 118) This drop from the Preloscica gravity-spur of Preloscica, which topographically falls entirely within the confines of the Kupa-Sava lowlands, is of the same order as drops in gravity at the edge of the Zagreb Forest and of the Moslavina mountains.

The higher part of the E flank of this spur, up to the +13 mgal. isogam, still shows the fairly considerable gradient of 1.6 mgal./km., while the lower part flattens out more and crosses the Sava lowlands in the Dolnji Bogicevci section in company with isogams that then strike N and S.

If we now follow this spur's axis that plunges towards the NE (Profile 117) the moderately strong gradient of 1.3 mgal./km. at first appears between the +25 and +19 mgal. isogams. Thereupon a saddle-shaped and strong shallowing between the +19 and +17 isogams follows at Graduša-Lonjak, E of Preloscica, and here the gradient is only 0.5 mgal./km. This may possibly indicate a structure of oil-geologic significance in this area, which for the most part lies within the limits of the former Yugoslav State Concession. A steeper drop then follows between the +17 and +13 mgal. isogams, with a gradient of 1.6 mgal./km. But then the gradient becomes very weak again towards the shallow syncline S of Osekovo (+9.5 mgal) and amounts to only 0.6 mgal./km.

(2) The Sisak Area (Profile 118)

The Sisak drilling field lies fairly deep on the N flank of the Preloscica gravity-spur, namely at between the +10 and +9 mgal. isogams. (Profile 118) The synclinal axis of Streljacka is now only 4 km. away. The gradient is fairly low and holds at around 1 mgal./km. throughout the drilling field. The isogams trend from SW to NE. The gravimeter surveys gave no indication of any special gravity-structure. In contrast, however, two shallow domes were delineated by various geological workers from the results of about 50 shallow wells drilled near Sisak. These domes, striking from SE to NW, were located in the Paludinen layers, with centers respectively in the Caldovo suburb of Sisak and in the Sava loop near Ter. The interpretation of the results from the shallow drilling, however, could obviously not always be entirely unambiguous, and the various geologists also did not always follow a uniform procedure. The conclusion was drawn from these results that, besides the uplifts mentioned, there also existed a fault striking from NE to NW, which would cause some 15 m. subsidence of the NE half of the Caldovo dome. Many of the shallow wells encountered small amounts of gas in the Paludinen layers at depths between 30 and 200 m. at pressures running up to 10 atmospheres absolute pressure. In the deep wells, of which two reached substantial depths at 966 m. and 1025 m. respectively, small amounts of gas were similarly encountered, together with large quantities of hot mineralized water.

Deep Well 4 near Sisak, spudded in about +9.? mgal., encountered the following profile:

0 - 275 m	275 m.	Paludinan layers
275 - 678 m	403 m	Rhomboidal layers
678 - 1015 m	337 + x m	Valenciennesian layers

The dip of the strata encountered was very slight.

If we compare this well with the Osekovo I well, only 19 km. away, which was sunk at +10.3 mgal., or almost the same gravity value, we see that the upper edge of the Valenciennesian lay at 1015 m. at Osekovo, or roughly 300 m. deeper than at Sisak, and that there this layer had not yet been completely penetrated after drilling through it for 705 m. It might accordingly be assumed that, at Sisak too, perhaps only half of the Valenciennesian had been pierced, so that there would still be a possibility of encountering gas and oil deposits in the Lower Valenciennesian. But the gentle dip of the layers, in the Paludinan near the surface as well as in the cores from the deep drilling, as well as the absence of any noticeable gravimetric relief, all lead to very serious doubts of the existence of any real structure at all at Sisak. The gases in the Paludinan are perhaps connected with some smaller fault. It would probably be better to regard the indications given by these gases as only encouraging signs for exploratory drilling on more clearly defined structures in the surrounding country (Martinska Ves, Pteloscica, Struzec, Osekovo.) We must still point out (see table on p. 38) that the wells in the neighborhood of Sisak (excepting the well at Resetari) were sunk at sites with lower gravity values than the other deep wells in

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Croatia, which is related to their positions near the gravimetric trough-axis.

(3) The Struzec-Osekovo Structure (Profiles 119-120)

The Struzec-Osekovo structure is demarcated at the blunted N end of Preloscica gravity-spur by a weak synclinal formation striking E and W. This structure was examined by torsion balance observations and a detailed gravimeter survey. It is elongated from E to W and consists of two parts. The longer westerly part is enclosed by the +10 mgal. isogam, while the shorter easterly part is enclosed by the +9.6 mgal. isogam. Both together are about 4 km. long and 0.5 km. wide. The westerly part of the structure has three small maxima at +10.65, +10.3 and +10.75 mgal. respectively (Profile 119.) A lateral axis radiates to the N from the middle one of these maxima and manifests itself over a length of more than 2 km. by causing bulges in the gravity contours. This part of the structure is separated from the main mass of the Preloscica gravity-spur on the S only by a narrow and shallow (+9.4 mgal.) trough. Towards the N, on the contrary, there is a stronger and longer decline to the S part of the Prepi-Okoli section of the Lonja-Sava geosyncline at +5 mgal. (Profile 120). The gradient between the +10 and the +5 mgal. isogams is 1.5 mgal./km. The W end of the structure is marked by a small gravity-precipice, over which the value plummets from +10.65 to +9.3 mgal. in only 200 meters, giving the equivalent of a gradient, in kilometer, of 6.5 mgal./km. Torsion balance measurements, however, show only a moderate gradient at this point. It is probable that this gravity precipice is due to a fault striking from N to S, at the foot of which the planned Struzec test-boring was located.

In the E the W part of the Struzec-Osekovo structure dips slowly, to emerge almost immediately again at the small high in Dolnje Selo, E of Osekovo, where there is a small maximum of +9.7 mgal. The N slope of this easterly part of the structure is the immediate continuation on the E of the N slope of the westerly part, only that the gradient of 1.2 mgal./km. is somewhat weaker. On the other hand, the S flank of this E part is more clearly defined than in the W part, because the Preloscica high no longer adjoins the structure, but on the contrary the S flank is able to pass over directly into the W part of the Gracenica-Dolnji Bogicevci section of the Sava geosyncline. The axis of the Osekovo structure then turns, slowly plunging farther, towards the gravity-pass of Gracenica on the SE, which it attains at the gravity-level of +9.3 mgal. Profile 11y).

The most remarkable feature about this E part of the Osekovo structure is another fault discovered by the torsion balance survey, which fault strikes through the axis of the structure from SE to NW. The heavy masses lie N of the fault, and thus the N wing is probably the elevated one.

Osekovo well No. 1 was sunk on this N wing of the fault, on the dome of the anticlinal axis that connects directly with the fault. The drilling site was located between the E and W maxima of the Osekovo structure at +9.6 mgal. The following profile was encountered:

0 - 16 m	16 m	Diluvium
16 - 205 m	189 m	Upper Paludinan layers
205 - 300 m	95 m	Middle Paludinan layers
300 - 710- m	410 m	Lower Paludinan layers
710 - 1014 m	304 m	Rhomboidal layers
1014 - 1419 m	405 m	Upper sand-poor zone of the Valenciennesian layers
1419-1718.7 m	300 + x m	Middle, sandy zone of the Valenciennesian layers

Down to about 600 m. the dip of the layers was about 2[illegible] degrees, from then on down the dip was moderately steep, ranging irregularly between 30 and 60 down to 1325 m. At that point a fairly strong dislocation was encountered, and from there down to the terminal depth of 1718.7 m. a smaller dip of between 3 and 7 degrees was observed. In the upper and middle parts of the well, many striations crossed it at angles of 50 to 60 degrees. The strong and variable dip of the strata cannot be connected with the weak uplift structure, nor can the numerous striations. Both are phenomena which accompany the fault displacement proved to exist by the torsion balance measurements.

The great thickness of the Pliocene sediments agrees well with the relatively low gravity value of +9.65 mgal. (see p. 3[illegible]). It is to be assumed that beneath the middle sandy Valenciennesian beds, in which drilling of Osekovo I finally stopped at 1718 m. depth, there are still about 300 m. of Lower argillaceous Valenciennesian marls, and beneath these still about 400 m. of White marls, Sarmatian and Mediterranean II. If it is further assumed that there are still about 400 m of Oligo-Miocene Lacustral formations deposited beneath all of these, the basement of the Tertiary would then be located at a depth of some 2800 m.

Without doubt the great thickness of the sediments at Struzec-Osekovo is favorable for oil prospects. The attitude of the layers, which have receded far towards the interior of the basin, is less favorable, as is the -- on the whole -- blurred and uncertain gravity relief, the context and implications of which became entirely clear only as a result of supplementary gravimeter studies made after the [illegible] drilling [illegible]. Still, the disadvantages of the weak fold-tectonics may be outweighed by the strong fault-dislocations which certainly do exist. Thus a further trial of this structure by another exploratory well -- Struzec I -- appears justified, the more so since there were distinct showings of gas and faint traces of oil encountered in Osekovo I, even though the deepest and preponderantly promising sand-horizons of the Valenciennesian formations had not yet been reached.

(D) The Massifs of More Ancient Mountains S of the Dolnji Doricevcinova Gradiska Section of the Sava Geosyncline

(1) The N Slope of the Prosara Mountains (Profiles 121-123)

The gravimeter surveys only located the true S edge of the Sava geosyncline again, further to the E, on the N edge of the crystalline Prosara mountains. A gravimeter traverse was run along the entire N edge of these mountains, from the E tip near Bistrica to Braksenic in the vicinity of the W tip, while transverse profiles were run from the E and W ends of this longitudinal profile down to the axis of the Sava trough. It might have been expected a priori that the longitudinal profile immediately along the end of the crystalline massif would show only insignificant differences in gravity. This did not prove to be the case, however. Two maxima of +20.3 and +25.15 mgal. respectively appear on the E and W ends of the massif. The gravity values between them sink to a level of +13.9 mgal. near Orahova (Profile 121). These substantial gravity differences should be attributed exclusively to petrographic differences within the crystalline formations. According to Katzer the crystalline schists of the Prosara planina are composed of gneisses, mica schists, quartz schists, green schists and phyllites. Green schists, for instance, are mentioned by him as occurring on the Kartar Hill at the W end of the chain and are probably responsible for the high gravity value of +25.15 mgal.

There are various plutonic granite formations intercalated in the crystalline schists. According to Katzer these are granitic intrusions of microgranitic-porphyritic marginal facies. The strongest of these intrusions is immediately W of Orahovo; and it is precisely here that the lowest gravity values -- +14 to +16 mgal. -- were noted. These are the lowest values ever observed directly over crystalline basement rock anywhere in Croatia. (See table on p. 65.) The experience in the Moslavina mountains repeats itself here: the granites are considerably lighter than the crystalline schists. How low these values on the granite of Orahovo really are, may be seen by comparison, for instance, with the Gojlo structure, where with a gravity of +18 mgal. the basement rock lay all the way down to 2156 m. depth. This comparison warns us again not to try to draw conclusions about the exact depth of the crystalline basement rock under unknown areas from the milligal values alone.

The variations in the gravity values over the Prosara crystallines also make it harder to demarcate the massif under the Sava alluvium. Katzer already suspected that the crystallines extended northward for some distance yet under this alluvium. The area above the +24 mgal. isogam on the transverse profile from the W end of the longitudinal profile to the Sava syncline at Jasenovac is certainly still on crystallines hidden under Sava alluvium, so that these rocks would accordingly extend at least 2 km. further N than the topographic mountain edge indicates. (Profile 122.) N of here the gravity falls to +3 mgal. in 6.2 km., giving the high gradient of 3.5 mgal./km. (Profile 122). This gravity-precipice is almost as sharp as towards the Sava graben on the N side of this section on the S edge of the Psunj mountains. Accordingly a strong fault displacement may also be assumed on the N edge of the Prosara mountains. Both these marginal faults taken together are responsible for the graben-like character of this portion of the Sava geosyncline.

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In any case the area above the +18 mgal. isogam on the E end of the Prosara mountains still belongs to the domain of the crystallines. (Profile 123.) This means that the crystallines here extend at least 2 km. beyond to the N and to the E into the Sava plain beyond the topographic end of the mountains near Bistrica. It is also entirely possible, however, that the whole area further to the E, as far as Stara Gradiska and down to the +14 mgal. isogam, still belongs to the domain of the only superficially covered crystalline. This view is supported by the generally low gravitational gradients in this area and by the fact that values as low as +13.9 mgal. have been noted on the outcropping crystallines of the Prosara mountains.

In this case the small pass-like gravity-trough 3 kilometers W of Stara Gradiska would probably be due only to petrographic differences within the crystallines themselves.

Moreover the great triangular stretch of alluvial depression of the lower Vrba, between the Prosara and the Kotajica mountains, remains unsurveyed, so that it is still undecided whether there is a wide connection between the Pannonian of this area, which frequently crops out at the margins of this depression, and the Pannonian of the Sava geosyncline, or whether it is separated from the latter by a ledge of basement rock connecting the Prosara and Kotajica mountains.

The gravity falls off sharply towards the N from the +14 mgal. isogam near Stara Gradiska down to the -10 mgal. isogam, which is reached in 7 km., giving the high gradient of

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3.4 mgal./km. here as well. (Profile 123) This is the E continuation of the marginal fracture of the Prosara mountains encountered S of Jasenovac. This fracture, N of Stara Gradiska, leads to the very deepest part of the Sava Geosyncline near Dolnji Bogicevci, where -13/65 -13/65 mgal. is attained.

(2) The NE Slope of the Motajica Mountains. (Profiles 124-125)

The S boundary of the Sava geosyncline is reached again by the traverse further to the E, on the NE edge of the Motajica mountains. However, from Kobas to Dugocac observations were made only on the N bank of the Sava, and thus somewhat to the N of the topographic mountain edge. According to Katzer, the principal massif of the Motajica planina is formed by a mighty granite stock, which is semicircularly surrounded on the S by a strip of gneisses and mica schists, followed by a wider zone of phyllites, on which transgressing Eocene sandstones are deposited, in the S. On Larkovac Hill, the spur projecting from the E end of the Motajica planina towards the lowest stretch of the Ukrina, the bedding conditions seem particularly complicated on Katzer's 1:200,000 map. The base of this hill massif, which is 700 m. high, would, according to this map, consist of Oligo-Miocene Lacustral formations. According to Katzer's "Geology of Bosnia" (p. 124) whitish Limnocardia marls presumably of Miocene age, directly overlie the phyllite schists at Korovi, on the bank of the Sava. But it is probably more likely to be Pannonian Limnocardia marls, since while there is a plentiful occurrence of Congeries in the Oligo-Miocene

Lacustral formations of Bosnia, Limnocardia have not been identified with certainty anywhere there, and especially "large coarsely-ribbed forms with limonitized shells" (Katzer, The Fossil Coals of Bosnia and Herzegovina, vol. I, p. 254). According to the above-mentioned map, the Lacustral formations are overlain partly by Leitha limestone and partly directly by Sarmatian beds.

The gravity profile along the left bank of the Sava begins 2 kilometers NW of Kobas and extends down to the wide bend of the Sava near Dubocac (Profile 124.) Since this profile travels from the central granitic core of the Motajica mountains out into the Tertiary approaches of the Parkovac Hill, the gravity might be expected to decline in this direction; but the contrary occurs. 2 km, NW of Kobas, right opposite the main granite stock of the Motajica mountains, the low gravity of +4.3 mgal. was observed. At this station the outcropping granite S of the Sava is only 600 m away. Although it has been shown in the Prosara mountains, that a value as low as +13.9 mgal. can occur even immediately above granite, one would still be unwilling to assume, without first being confronted by convincing proof, that granite still crops out directly under the alluvium at the very considerably lower gravity value of +4.3 mgal. It is more likely that at Kobas, N of the Sava, there are already Tertiary formations of greater thickness under the alluvium. This would mean that the topographic NE edge of the Motajica mountains would exactly coincide with the marginal disruption of these mountains from the Sava geosyncline and that the Sava river would flow here along that marginal disruption. This view is further supported by the fact that the isogams strike from SE to NW up to a point 2 km. SE of Kobas and thus parallel the NE edge of the Motajica mountains, with the gravitational gradient pointing steeply to the NE, thus away from the Motajica mountains. Further towards the NE, however, the gravity values rise along the Sava, and reach +15 mgal. opposite Korovi. During this rise the isogams appear to run almost perpendicularly towards the edge of the mountains. Obviously, as in the Prosara mountains, the increase of gravity in this direction is connected with the fact that the E tip of the mountains is formed of crystalline schists, which are heavier than the granitic core. The Tertiary then transgresses at Korovi upon the phyllites of the Motajica mountains. A further rise in gravity then follows along the Tertiary margin of the Karkovac Hill, until it reaches +18.8 mgal., the highest point in this profile. (Profile 124) It is probable that heavy crystalline schists at shallow depths here underlie the Tertiary. The gravity then declines slightly to reach +17.05 mgal. at the bend of the Sava, near Dubocac, thus marking a slight gravity-trough to the S of the gravity-spur of Zbijeg, to be discussed below. According to Katzer (op.cit., vol. I, p.256) lignitiferous lacustral depositions occur at Bosnian Dubocac, and contain "Cypris, Bythynia and strongly swollen, delicate-ribbed Limnocardia." These beds dip gently to the SW. In this case as well it is not clear whether they are Oligo-Miocene lacustral formations or Pannonian beds.

Comparison of the low gravity values on the edge of the Motajica mountains with the values of the whole surrounding area shows that they are also particularly low on the opposite side, on the domal uplift of Kasonja, on the N flank of this section of the Sava geosyncline. (P. 108) This data alone was enough to support the conclusion that there must be a regional gravity-deficit apparently extending, more perpendicularly to the Sava valley, from the Kasonja dome to the Motajica mountains. In contrast, the gravity rises strongly again further E, towards the area S of the Sava, so that large areas of the Vucjak mountains lie at gravity-levels above +30 mgal.

From Kobas the gravity drops from +4.65 mgal. at the edge of the Motajica mountains to reach -5.5 mgal. to the N, in the Orijovac section of the Sava geosyncline. (Profile 125) The total difference in gravity thus amounts to only 10 mgal. This suggests that this section of the Sava geosyncline around Orijovac, which is also constricted to a width of only 7 km. by the Motajica mountains on the S and the Kasonja dome on the N, has not subsided very deeply. The gravitational gradient -- 4. mgal./km. -- is, however, one of the most substantial found in the entire survey area, and indicates that the N marginal fracture of the Motajica mountains descends abruptly into the abyss.

(3) THE VUCJAK MOUNTAINS (Profiles 126-133).

(A) THE MAIN MASSIF OF THE VUCJAK MOUNTAINS

There is a fundamental change in the geological conditions of the Vucjak mountains, in that the Sava graben is bounded on the S no longer by the crystalline mountain core, but by a Dinaric Streichendes folded mountain range, predominantly composed of Eocene and Oligocene formations. The fact that this mountain range is skirted on almost every side by Leitha limestone and in many cases by Pannonian as well shows that besides undergoing one early Tertiary folding its entire extent -- which is about 100 kilometers long and about 25 kilometers wide from the Drina to the Ukrina -- was also uplifted a second time as a great crest at the end of the late Tertiary. Three divisions of the whole range can be distinguished.

(1) The Majevica mountains near Tuzla;

(2) The central section of the range on both sides of the small Tinja river;

(3) The Vucjak mountains between Bosna and Urgina Ur Ugrina.

Greater elevations, running to around 900 meter, are reached only in the Majevica Mountains, which are principally built up of thick series of marine Eocene depositions and Oligocene Lacustral beds. These beds are folded into a series of anticlines and synclines. Numerous wells, some of them over 1500 meters deep sunk along the anticlinal axes, have tapped the small oil deposits around Tuzla.

The central section of the range is principally distinguished by a long and narrow chain of Mesozoic rocks which have intruded upon the Eocene.

The Vucjak Mountains are a thickly settled low highland area with elevations of 250-300 meters above sea level. Accordingly, the loam cover is thick and like rock is exposed. According to Katzer's 1:200,000 map, the range is mainly composed of Eocene sandstones with marlaceous shales and shaley clays. The map fails to show whether these Eocene rocks are still folding as much as they are in the Majevica mountain, for it does not distinguish subdivisions or show any signs of indicating fall. Katzer does, however, show steeply folded Eocene beds beneath the carboniferous Oligo-Miocene Lacustral deposits in his profile of Kotorsko in the lower Bosna Valley. The Vucjak Eocene is connected on a wide front in the SE with the Eocene of the central section of the range beyond the Bosna. At the other margins, late Tertiary depositions transgress upon the massif.

Near Derventa is the important point where the transgression of Leitha limestone over Oligo-Miocene Lacustral Deposits was first observed by Paul and Horne and afterwards by Katzer. According to Katzer's map, Leitha limestone borders surrounds the entire S margin of the massif, while Oligo-Miocene Lacustral deposits borders surrouns the NW and E margins. It is, however, questionable whether all the formations designated on the map as Oligo-Miocene Lacustral depositions really do belong to that category. Katzer states that on one of the most important exposed areas, the steep bank of the Sava on the Karda Hill near Svilaj, there are gray, very sandy, argillaceous marls with small, fine-ribbed Cardies on the bottom, overlain by white, finely laminated marls with juvenile forms of congerie and Pisidia. Katzer himself found any definite determination of age to be accordingly impossible. The Cardia would suggest Pannonian rather than Oligo-Miocene. The beds here dip gently to the NE, which agrees with the gravimetric data.

Katzer also mentions the occurrence of marls with small Cardia on the E margin of the Vucjak mountains in the Upper Kaludjerovac graben NW of Pecnik. Although these marls are said to lie under the Sarmatian there, on the 1:200,000 map they are shown as following the Sarmatian limestones on the vertically overhanging slope and thus probably similarly belong to the Pannonian.

On the other hand, according to both the description and the map of Katzer, the marls containing Cypris follow horizontally upon the Leitha limestone and are, accordingly, Oligo-Miocene.

We must add that the Eocene and Oligocene depositions of the Majevica mountains* are ordinarily designated as Flysch-Vucjak* or Flysch-type formations. In common with the typical Flysch formation, they possess the general lithological character of being a thick sequence of clays, marls, sandstones and conglomerates, and belong similarly, moreover, to the Early Tertiary. But there are important differences; in Eocene times there was a rich marine littoral fauna in the Majevica mountains, and this is hardly the case with normal Flysch formations. Moreover, the Flysch is a typical rock of the outer margins of the Alpine mountains, but in the case of the Majevica mountains we have depositions instead from the inner margin of the Dinaric mountains.

The young chain-formation mountains of the type of the Alps, the Himalaya, etc., are gravimetrically characterized by deficits of mass. These minima carry over into the marginal geosynclines of the mountains, for instance to the Upper Bavarian Molasse syncline bordering the Alps. The Vucjak Mountains, however, were found to be a strong maximum with gravity values from +30 to +34 milliglas. Thus the presence at first of a minimum as well might have been expected in the Early Tertiary folds on the margin of the Dinaric Mountains, but the opposite is the case. Thereby it takes its place in the series of the other gravity massifs in Croatia N and S of the Sava, all of which usually have cores of crystalline rocks. The gravity values in the Vucjak mountains (see p. 65) are comparable to those over the gneiss of the Moslavina mountains, and higher than those over the gneisses, phyllites and green schists of the Prosara mountains (+15 to + 25 mgal). Since naturally no particularly high specific gravities may be assumed for the Eocene rocks of the Vucjak mountains, the conclusion can be drawn that heavy crystalline schists directly underlie the Eocene at levels close to the surface. The Vucjak mountains are therefore probably, in their deeper core, a small crystalline massif like the Motajica and Prosara mountains.

Ordinarily gravity traverses do not proceed far into the interior areas of crystalline massifs, but the Vucjak hill-country was completely covered between Derventa and Medrica, remaining throughout on top of Eocene basement, according to the Katzer map. The gravity values ranged uniformly between +28 and +31 mgal and there were no marked gravitational gradients. (Profile 126). So weak a gravity-relief was observed elsewhere only in broader gravity-depressions, such as parts of the Drava geosyncline.

The pronounced N and S course of the isogams of the W and E flanks of the massif is remarkable, as is the E to W course of the isogams of the N flank, which all result in the strikingly square shape of the massif.

The S part of the W flank falls towards drops from +28 to +22 mgal towards Lusane, with a gradient of 2 mgal/km (Profile 126). According to the Katzer map, Sarmation outcrops on the upper part of the gravity-slope, while Oligo-Miocene Lacustral beds crop out on the lower part. The gradients thus appear to be directed towards the McMarkovac Hill on the other side of the Ukrina, which probably represents a synclinal zone opposite the gravity-spur of Zbijeg, which we shall now discuss.

(b) THE GRAVITY-SPUR OF ZBIJEG. (Profiles 127-129).

For there is a well-defined gravity-spur extending westward, from the NW corner of the Vucjak mountains on the bank of the Sava S of Klakar, into the area of the Ukrina confluence and across the Sava to the Zbijeg region. The presence of this gravity spur was all the more surprising from the absence of any topographic indication over its course through the alluvial plain of the Sava and the lower Ukrina. It measures 22 kilometers from end to end, and is thus fairly long. Along the axis (see Profile 127) the gravity falls from +4 +34.2 mgal at the Sava river S of Klakar to +20 mgal at Zi Zbijeg. It also falls sharply from this axis towards the Brod section of the Sava graben on the N. Thus it falls from +28.75 mgal at the village of Kolibe to +9.1 mgal at Eroa Brod (Profile 128). In the course of this fall, the gradient between the +29 and the +10 mgal isogam amounts to 2.4 mgal/km and is thus rather high. At the W end of the gravity-spur near Zbijeg, the gravity is +21.4 mgal and falls similarly to +3.5 mgal in the area of Slatinik in the Sava syncline, giving a gradient of 2.5 mgal/km (Profiles 128-129). In contrast, there is only a small drop towards the S. In the E part of both transverse profiles, the gravity falls from +28.75 mgal at Kolibe to +23.5 mgal at Humka. (Profile 128), giving a gradient of only 1.1 mgal/km, while in the W transverse profile in the Zbijeg area (Profile 129) the gravity falls only from +21.2 to +17.05 mgal, giving a gradient of 1.4 mgal/km.

The question as to the geological significance of the gravity axis now arises. According to the Katzer map, Oligo-Miocene Lacustral formations outcrop at Klakar, where the gravity-spur begins, as well as S of the W end of the axis, namely, on the Markovac Hill S of Zbijeg-Dubocac. The latter, however, seems uncertain, as Katzer also mentions "swollen, delicate-ribbed Limnocardia", which would point rather to Pannonian. In any case, however, the southwestward dip of the carboniferous series near Dubocac, which Katzer mentions, would fit in with a domal uplift running N of here, near Zbijeg. In the present state of our knowledge we may assume that Oligo-Miocene Lacustral formations outcrop in general beneath the alluvium along the ridge-line of the axis, with Late Tertiary perhaps in the W part. Accordingly, and in view of the weak gravimetric relief of the S flank, the axis of Zbijeg has probably no particular significance for oil exploration.

The N flank of the Vucjak mountains also falls off rather strongly. However, the gravity-differences between here and the Sava syncline fall decline, since the latter rises here to the gravity-pass of Bicko Selo. The gravity thus falls from +32 mgal S of Dolnja Bebrina to +17.85 mgal at the gravity-pass of Dolnja Bebrina. In the course of this decline, the isogams project from Vucjak massif towards the gravity-pass of Bicko Selo, indicating a plunging axis in that direction. An even more substantial gradient rules at the NE corner of the Vucjak massif (Profile 130). The gravity falls from +32.5 mgal SW of Svilaj to 7.5 mgal at Velika Kopanica. The high gradient of 4.6 mgal/km rules in the upper part of this profile between the +30 and the +11 mgal isogams, from which it follows that the NE corner of the Vucjak massif was formed by a powerful fault displacement striking from SE to NW.

The E flank of the Vucjak mountains also falls steeply from Bosnian Samac towards the Sava syncline. It is worth while noticing that this E flank strikes due N and S. The gradient is especially steep near Modrica, where the gravity falls in 1600 meters from the +30 mgal to the +20 mgal isogam, giving 6.2 mgal/km. Geologically, the areas where Eocene is covered by Oligo-Miocene Lacustral formations runs approximately along the +30 mgal isogam.

(c) THE GRAVITY-SPUR OF ODZAK. (Profiles 131-132).

The E flank of the Vucjak mountains shows no signs of uniformity in its decline towards the graben of Bosnian Samac, but in the Odzac area, instead, there is a well-defined terrace-like gravity-spur. The gravity falls at first from +32 mgal at the E margin of the Vucjak mountains to +25 mgal at Prnjavor, giving the high gradient of 3.5 mgal/km. But then over the next 2 kilometers there is only the very weak further decline to +23 mgal, forming the pronounced gravity-plain of Odzak. (Profile 131). From this plain the gravity then sinks rather steeply again at 2.5 mgal/km into the Sava syncline at Bosnian Samac, where the deep point of the syncline is reached at +7.5 mgal. Profile 132 shows a cross-section through the gravity-spur of Odzak. This cross-section shows, better than the longitudinal profile, the probable saddle-type nature of the structure. Towards the Sava syncline of Velika Kopanica on the N there is again a strong decline. In contrast, the syncline of Cardak on the S is only depressed to a gravity-level of +18.5 mgal, so that the difference from the high here is only 5 mgal. It should, however, be noted that the gravity-stations were so widely spaced as only to touch, to do no more than touch, the core of the high. Precisely here further and detailed precision gravity surveys would be in order.

The gravity-plain of Odzak appears worthy of attention because it recalls the similar petroliferous structures of Peteshaza (Profile 3), Gojlo (Profiles 40-41), gasi-ferous structures of Sumecani (Profile 35) and Resetari (Profile 65) as well as the promising structures of Foresters Lodge Vukovce, (Profile 19), Ivanopolje Glass works (Profiles 49 and 51), Kozarica (Profile 56), and Martinska Ves (Profile 115), and also because the bravity-level of +23.5 mgal allows us to postulate a sufficient thickness for the Tertiary formations. These considerations are reinforced by the distance of only about 65 kilometers from the oilfield of Tuzla -- a distance which is not too great -- even though oil at the latter place occurs in the Early Tertiary under geologically unclear conditions. The Odzak structure thus deserves to be kept in mind for further investigations.

(d) THE GRAVITY-SPUR OF GRADACAC (Profile 133)

The edge of the Vucjak mountains projects towards the NE at Gradacac towards the Sava plain. According to gravimetric data, this projection then continues further towards the NE, beneath the surface. This plunging axis is mainly the result, gravimetrically, of the fact that the isogams run E and W to the N of Gradacac, and N and S to the E of it. The axis begins at Gradacac itself with the gravity of +27.3 mgal over outcropping Leitha limestone, which according to Katzer transgresses there upon Cypris marls belonging to the Oligo-Miocene Lacustral formations. These marls overlie the Flysch-type Eocene rocks of the Vucjak mountains. The axis then slopes rather uniformly towards the NE until it reaches the Sava syncline at

Bosnian Samac. (+7.6 mgal.) The gradient only becomes steeper in the central section, between the +20 and +14 mgal isogam where it rises to 2.4 mgal/km (Profile 133). The Sarmation probably crops out on the surface on the slope above the Leitha limestone, and above that, on the Podgorica Hill, NE of Gradacac, the Pannonian oloows follows in unknown development and thickness. If future investigations of the gravity plain Odzak should yield favorable results, the gravity-spur of Gradacac also deserves closer attention.

REVIEW OF THE STRUCTURES SURVEYED

Now that we have completed the detailed discussion of the survey-areas, taken one by one, it appears advisable to cast a backward glance on the gravimetrically determined tectonic forms and to compare them. Abundant material for such a review is furnished by the accompanying 133 gravity profiles.

I. BASEMENT ROCK MASSIFS

It probably happens only infrequently, as a general rule, that gravity meter surveys for use in locating oilfields stand directly over crystalline basement rock. But in Croatia this often occurred. The reason for this is that the small Croatian basement massifs extend everywhere in Croatia up to the very edges of the Tertiary graben with good prospects of oil, so that occasionally (Mikleuska) even the fragmentated marginal disruptions of the basement rock themselves become saturated with oil. In general, as will be readily understood, the surveys do not penetrate far into the interior of the crystalline massifs. But even without doing so, it was still possible to determine a number of remarkable facts.

The gravity-anomalies observed directly over the crystalline basement rock of the Moslavina, Psunj, Krndja and Prosara mountains are presented in the table on page 65. It will be seen that over granites, gravity values ranging between +14 and +25 mgal were observed, over gneisses, from +18 to +31 mgal, over gneisses and amphibolite schists, from +34 to +38 mgal, over phyllites and Silurian schists from +40 to +50 mgal and, finally, on basalts and amphibolite schists, from +50 to +55 mgal.

As a general rule, gravitational gradients are low immediately above the massifs, so that the gravity curve is very flat. This is shown by Profile 38 of the NE part of the Moslavina mountains, Profile 42 of the southern part thereof, Profile 20 of the edge of the Papuk mountains, Profile 26 of the Krndja massif, and Profile 69 of the E side of the Psunj mountains. And, conversely, the flat course of the gravity curve taken over the Vucjak mountains (Profile 126) gives us reason to suspect that basement is similarly present here at shallow depth beneath the transgressing Eocene.

The varying gravity values on the crystalline rocks result in the occurrence in the domain of the crystalline massifs of gravity lows and highs due only to petrographic differences. Thus minima occurs above granites in the Moslavina mountains

(Profiles 36-37) and in the Prosara Mountains (Profile 121) which if it were not for the petrographic composition of the basement rock could be interpreted as troughs. (Compare the effect of salt stocks on the gravity pattern!) The minimum between the highs of Gorjani and Selci (Profile 91) should probably be interpreted in the same way.

On the other hand, the closed high at the SW corner of the Moslavina mountains (Profiles 36-37) is exclusively due to the occurrence of heavy crystalline schists in this area. It can probably also be assumed, by analogy, that the shallow highs at Selci, Mrzovic, and Sirokopolje on the Dakovo mass, are all substantially due only to the occurrence of particularly heavy crystalline rock within this mass (Profiles 89, 90 and 92) so that in this case we are not dealing with structures in the true sense of the word.

The influence of the varying densities of the crystalline rocks can, finally, go so far as to make the gravity gradient run in opposite sense to the tectonic gradient. This is the case on the N margin of the Motajica mountains, (Profile 124), where the gravity is lowest -- +4 to +5 mgal -- opposite the granite in the center of the massif, while they have risen as high as +12 mgal opposite the crystalline schists at the E end of the massif, and, finally, they go up to +18 mgal on the Tertiary piedmont in the SE, on the Zbijeg gravity-spur.

The level of the gravity values and the form of the gravity curve permit us, finally, to recognize the presence even of shallow outcropping basement rock in areas where this was hitherto not known, and not even suspected. This is the case in a rather large area which connects upon the N and S with the hitherto known crystallines of the Moslavina mountains. (Profiles 38, 40 and 42.) An even larger crystalline mass, hitherto unknown, must run through the area between the E margin of the Pozega fault-pit and the Dakovo region (Profiles 71 and 89.) It has already been pointed out above that the "highs" of Sirokopolje and Mrzovic, adjoining on the E, probably also belong to this mass. (Profiles 89-90.) As has been mentioned, there is also good reason to suspect in the case of the Vucjak mountains -- since these also constitute a subsurface crystalline mass -- that the Eocene which crops out on the surface is present only in slight thickness. (Profile 126.)

II. MARGINAL DISRUPTIONS OF THE BASEMENT

The crystalline massifs usually show steep faults and flexures at their displacement against the deep Tertiary graben. In this way the light Tertiary sediments of great thickness are in immediate contact with the heavy crystalline rocks, resulting in great differences of gravity and steep gravity-curves. Such margins of disruption are exhibited by a whole series of profiles of the Moslavina mountains: Profiles 36 and 37 of the SW corner, Profiles 39, 40 and 42 of the S slope, Profiles 43, 44 and 46 of the E declivity, and Profile 38 of the NE corner. The steep E flank of the Zagreb Forest is portrayed by Profile 111. The very steep W margin of the Papuk mountains at Daruvar is shown by Profile 39, the deep drop from the N margin of this massif down to the Sava graben is shown at Vocin by Profile 20 and at Pusina by Profile 24. The N precipice of the Krndja massif is shown at Orahovica by Profile 25, the N and S precipice of this small massif is shown further to the E by Profile 26. A series of profiles shows the disruption from the S margin of the Psunj massif against the Sava geosyncline, which is very deep in this area: Profile 62: Bijela Stijena - Okucani; Profile 63: Sagovina-Dolnji Bogicevci; Profile 64: Sumetlica-Nova Gradiska; and Profile 65: Podvrsko-Resetari. Profile 69 shows the E disruption of this range against the Pzega fault-pit, while Profile 70 shows the N disruption of the Pozega mountains, here built up of crystallines and late eruptives against the Pozega fault-pit.

The N and S disruption of the hitherto unknown Dzokovo massif may best be seen from Profile 91. The N disruption of the Prosara mountains from the Sava graben is seen in Profiles 122 and 123, while that of the Motajica mountains is shown by Profile 125. At the extreme E, finally, the W section o dir disruption of the crystalline core of the Fruska Gora is represented by Profiles 96 and 97, while that of the S du disruption is shown by Profiles 98-99.

III. MARGINAL FRACTURES AND MARGINAL FLEXURES IN TERTIARY HIGHLAND AREAS

There are also a number of highland areas in the region surveyed where, although the crystalline basement of the Tertiary does not immediately outcrop to the surface, the gravity values are still so high that steep fractures and flexures with respect to the deep adjoining graben could be present. The flexure-like displacement of the Ludbreg structure against the deep Drava graben is a case in point (Profile 5). On the SE continuation of this displacement are the profiles showing the displacement of the Bilo mountains against the Drava graben: Profile 15 shows the N flank of the Sedlarica structure, Profile 17 the N flank of the structure at Vukovce Forest Lodge, and, finally, Profiles 20 to 23, which show the steep drop of the eruptive mass of Lisicine (+48 mgal) intruded into Tertiary formations, down to the Drava graben at Vaska (-4 mgal). This gravity difference of 52 mgal and the comparable difference of 51.6 mgal at the S disruption of the crystalline Psunj mountains are the highest drops ever measured at a gravity-precipice in Croatia (cf. table on page 25). Other pronounced gravity-cliffs occur on the S edge of the Tertiary hill-country projecting from the W margin of the Psunj Mountains into the Sava graben. To this group belong Profile 59, Paklenica-Nivska, Profile 60, Sisvoto Oil-Seeps to Paklenica, and Profile 61, Gelese-Dolnji Rajic.

East of the Psunj mountains as well there are steep marginal flexures and fractures on the S edge of the Pozega mountains, which are mainly constituted of Oligo-Miocene Lacustral formations; as at Bacindol (Profile 65), Dresnik-Adjamovci (Profile 66), Tisovac-Staro Petrovo Selo (Profile 67), and the Ostri Vrh Oil Seeps to Staro Petrovo Selo (Profile 68).

Further to the E there follow the disruptions between the Dilj mountains, on the axes of which Leitha limestones and White Marls crop out, and the Sava graben, as at Grizic (Profile 74), at Sibinj (Profile 73), at Brod (Profile 72) and at the Tomica anticline (Profile 100).

There is also a rather steep slope at the W flank of the Vrbanja massif, which was discovered by geophysical means. There are steep disruptions as well at the NE corners (Profile 130) and the E flank (Profile 126) of the Eocene Vucjak mountains. But, as we have repeatedly pointed out, this range presumably has a core of crystalline rock under a shallow Eocene cover.

IV. TERRACE-LIKE GRAVITY-PLAINS AT THE EDGE OF GRAVITY-CLIFFS

Many of the above-enumerated gravity-cliffs descend with uniform steepness into the depths, such as, for example, the S marginal fractures of the Psunj mountains. (Profiles 62-64). However, there are often terrace-like shallowings or plains interrupting the gravity-slopes. Since such shallowings can be of importance for oil exploration, and show up much more clearly on the profiles than on the map representations of the isogam-patterns, we list these shallowings in detail: At Vukojevce Forest Lodge (Profiles 9-10); at Gvozdansko, NE of Klisa (Profile 20); SW of F Cabuna (Profile 21); NW of Lukavac (Profile 22); Terrace of Dungeri and axis of Bokani (Profile 23); at Kraskovic, SW of Mikleuska (Profile 24); the gravity-terrace N of Orahovica (Profile 25); the Bunjani-Sumecani structure, whose terrace-like character appears most clearly from Profile 35; Sartovac (Profile 42); Ivanopolje Glass Works (Profiles 49-51); Dezanovac (Profile 49); Brestovac (Profile 50); Kozarica (Profile 58); Opatovac (Profile 65); Kasonja dome (Profile 75); Ilinci (Profile 96); Martinska Ves (Profiles 115-116); Drnica-Konak, on the Preloscica gravity spur (Profile 117.)

There are a number of gravity-shallowings at especially deep gravity levels in the neighborhood of gravity-depressions. The following are examples of this pattern:

	PROFILE No.
Feniceanci	26
Velika Trnovitica	44-45
Lipovljani	57
Kosetari	65
Ostri Vrh, Near Petrovo Selo	65
Crnkovci Gravity-Ledge	77-79
Sidski Banovci, on the W Foot of the Fruska Gora	97
Morovic, on the S Foot of the Fruska Gora	99
Trnjani and Staro Topolje	101-102
Banov Dol, on the Zupanja Massif	104-105
Osekovo	117-119-120
Odzak on the Vucjak mountains	131-132

However, as a rule the gravity relief of these structures is so blurred that further exploration is indicated only where there are other factors pointing to the likelihood of oil.

Finally, as a special case of terrace-like gravity shallowings in the course of gravity-cliffs, the saddle-type undulations on such terraces may be considered. The best example of this pattern is furnished by the Gojlo structure (Profiles 40-41). It should be recalled that this structure only appeared on the first reconnaissance gravity-survey as a terrace on a gravity slope. Of the structures already mentioned, thos of Bunjani-Sumecani (Profile 35), Martinska Ves (Profiles 115-116), Crnkovci (Profiles 77-79) and Osekovo (Profiles 117, 119 and 120) represent cases of similar though not so clear-cut undulations on gravity slopes. These structures deserve special attention in view of the occurrence of closed gravity maxima.

V. ANTICLINES

(A) Elongated, Tertiary anticlines with flanks of equal gravity and bounded on both sides by deep synclines. This type of anticline is represented in the survey area only by those of Selnica-Zaklenica (Profile 2) and Murska Subota (Profile 1). The former has broad terrace-like shallowings between the +9 and +11 isogams on its NE flank at Peteshaza and Velyifalu; these have recently proved to be petroliferous. (Profile 3).

(B) The Selnica anticline also possesses a strong axial gradient towards the E (Profile 4). Anticlines of comparable length with plunging axes are those of Ludbreg (Profile 6, Transverse Profile 5) and Poganec-Subotica (Profile 9, with Transverse Profiles 7-8).

(C) The shorter and wider plunging anticlines are more numerous.

They may be considered as sills or ledges projecting downward from the basement rock massifs into the Tertiary synclines. The following structures belong to this type:

	PROFILE NO.
Zerjavinec-Dugo Selo	112
Cazma-Vrbovec	29
Kriz-Sumecani-Ivanic Klostar	33
Preloscica-Osekovo	117-118
Lipic-Dujavica-Janjalipa	52
The same, with its small lateral sill S of Bujavica	53-54
Cagljic-Kricka-Novska	59
The Zdjer Sills plunging from the Vucjak mountains	127-129
Odzak	131-132
The gravity-spur of Gr Adasac	133
The Zupanja-Kladovac Axes which subside from the Zupanja-Vrbanja massif	104-105
Zupanja-Domaljevac	106-107
Vrbanja-Brecko	110

A spurlike continuation also projects downward into the depths towards the W from the principal axis of the Fruska Gora.

(D) Short elliptical domes were found more frequently than long anticlines.

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These include:

	PROFILE NO.
Lpe Lepavina	10
Jagnjedovac	11
Mosti	13
Sedlarica	15-16
Sumecani-Kriz	33-35
Gojlo	40-41
Osijek	81-82
Vera-Erdut	82-86
Jarmina	89 and 93
Mirkovci	94-95
Dubranec-Kravarsko	113-114

(E) The shallow scutellar gravity-highs constitute a special group of the elliptical domes, and originate from sills of basement rock at moderate depths. Grubisnopolje is the best example of this. Its flat gravity-relief may be clearly seen from Profiles 47 and 48. Mica schist was in fact already encountered at a depth of only 1029 meters. The Rascani structure, E of Krizevci, shows a similar if somewhat more plainly defined gravity relief (Profiles 27-28). The gravity-relief is comparably blurred on the extensive gravity-high of Zupanja-Vrbanja (Profiles 103 and 106), even though there are occasional steeper inclinations on the flanks (Profile 109). The structures of Osijek, Vera-Erdut, Jarmina, Mirkovci and Dubranec-Kravarsko, which have been listed in the second half of the above enumeration of the elliptical domes, also fail to exhibit much greater differences of gravity, so that the structure of the basement complex must also be similar in those cases as well.

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(F) Among the anticlinal structures of the survey-area the asymmetric type with sharply contrasting flanks are also very conspicuous. In most of these cases, one flank slopes strongly and steeply into an adjacent graben, while the other flank leads only to an insignificant tectonic trough which separates the structure from other gravity highs. The following examples may be given:

	PROFILA NO.
Ludbreg	5
Lepavina	10
Sedlarica	15
Vukovce Forest Lodge	17
Vrbovec Domal Uplift	32
Kriz-Sumecani Structure	34
Martinska Ves	115

The Gojlo structure can also be included in this group on account of its much more weakly developed flank (Profile 40), and certainly the Struzec-Osekovo structure with its particularly insignificant S flank belongs here (Profiles 117, 119 and 120).

(G) Finally there is a small group of anticlinal highs which are due to Tertiary eruptive stocks. To this group, in the very first place, belongs the strikingly high maximum of +46 mgal at Lisicine. (Profiles 19-20). The Nasice high of +34.5 mgal is probably also due to the presence of an eruptive mass. (Profile 26).

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VI. GRAVITY-PASSES.

In the gravity pattern of Croatia there are relatively frequent cases of relative gravity-minima in chains of high-gravity areas. These minima form what might be termed pass-like passages between gravity depressions. The gravity-sill of Medjuric-Janjalipa is an example (Profiles 52 and 56). On the one hand, it represents a subsidence between the highs of Gojlo and Lipik-Bujavica, and, on the other, a gravity-sill between the Sava graben and the Gaj syncline. Further examples are the gravity-passes of Kladovac (Profiles 92 and 104), Djeletovci (Profile 94), Vinkovci (Profile 94), Severic (Profile 114) and Gracenica (Profiles 117 and 119.)

VII. If, finally, we look at the arrangement of the highs into larger tectonic formations, a long anticlinorium stands out, with its chain of domes, extending from the Kalnik mountains over the maxima of Lepavina -- profile 10 --, Jagne Jagnjedovac -- profile 11 -- Mosti-Sv. Ana -- profile 14 -- Sedlarica-Cremusina -- profile 16 -- up to Vukovac Forest Lodge -- profile 16. The Lipik-Bujavica-Gojlo gravity-sill bears the domes of Bujavica, Janjalipa and Gojlo.

VIII. The system of folds radiating from the E end of the Ivancica and the Kalnik mountains is also a notable feature of the fold-tectonics. (See Sheet 1 of the 1:200,000 map.) Between the Drava graben and the syncline NW of Krisevci at the E end of the Kalnik mountains, there is also a gravity mass about 16 kilometers wide, which divides towards the E into the three axes of Ludbreg, Veliki Poganec-Subotica and Lepavina-Mosti-Sedlarica. The former two trend ENE, while the latter runs southeastward.

TECTONICS OF FOLDS AND TECTONICS OF FRACTURES

The survey-area was hitherto considered to be decidedly an area of fractured blocks. The Croatian buttes were thought to be the residual blocks of the shattered "Oriental mainland." Even such typical long and steeply upwarped anticlines as the Ivancica and the Kalnik mountains are occasionally called "horsts" even today in Croatia. But there cannot be the slightest shadow of doubt but that these mountain formations have a mesozoic core and that the Miocene and Pliocene strata that steeply envelop them are typical compression faults. This applies of course with equal force to the E continuations of these faults, where the Mesozoic has been buried under the covering Late Tertiary. Further to the N it has been shown by both exploration wells and geophysical surveys that the oil-fields of Selnica Peklenica, which occur in a hill country which gives little topographical indication of oil, are connected with a magnificent buried hill which manifests itself gravimetrically as a very sharply-defined maximum. The results of the drilling have also revealed, however, that this folding did not proceed without fracturing but that, on the contrary, the anticlines are shot through by numerous longitudinal and transverse fissures. A great slab displacement was discovered on the W continuation of the Selnica anticlinorium, in the Voc mountains. Similarly,

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fold tectonics strongly dominates over fracture tectonics in the N area of the so-called Sava-folds. It may be remarked, by the way, that these E spurs of the Alps further to the W in the area of Cilli and Trifail on the upper reaches of the Sava are designated by the name of Sava folds. Further E, on Croatian territory, these folds which strike from W to E, then however pass over into the river systems of the Mur and the Drava, while another form of mountain structure dominates the scene along the middle and lower course of the Sava.

It is true that here, too, pronounced folding of the Pliocene does occur, as at the Resetari anticline and the Gojlo dome. But it is precisely the gravimetric surveys that have shown that these are not cases of deep folds with cores of heavy rock but merely superficial undulations superimposed upon the downslope of the basement rock massifs.

On the other hand, gravity surveys have also shown the overwhelming importance of the basement rock massifs with mostly steep marginal fractures and marginal flexures in the structural geology of this southern area. For instance, there is a marginal flexure along the SE margin of the Zagreb Forest and also along the S edge of the Pozega mountains, as is shown in both cases by the long bands of Leitha limestone along the mountain edges. In contrast, the W and S edges of the Moslavina mountains the the S edge of the Psunj mountains, for instance, were formed by steep marginal fractures. On page 170 the marginal disruptions of the basement rock has been separately enumerated from the gravity profiles.

Sill-like bodies frequently plunge from the basement massifs into the Tertiary graben. These structures, which have been enumerated on page 174, are frequently similar to true anticlines, and their significance in oil exploration can also be the same. But they probably should not be considered true anticline formations resulting from lateral pressure.

The trough areas in the N and S parts of the survey-region vary in character, just as the highland areas do. The deep zones in the N (Luttenberg graben, Cakovec-Prelog graben) are distinctly folded troughs. On the contrary, the Lonja-Sava geosyncline together with its various bulges (Zagreb graben, Ilova gr aben), etc.) has mainly the character of a graben, in which the edges are mostly steep flexures but also, in places -- especially between Novska and Brod -- may be sharp fault disruptions instead. The edges of these graben are developed in a great variety of ways by the sills plunging from the basement rock and by the marginal folds as well. And it is just these marginal structures which here, for the most part, offer good prospects of oil. Whether the marginal folds are only an accessory phenomenon which occurred during the subsidence of the graben area or whether a late subsequent lateral pressure also contributed in part to their formation is a question we shall not discuss.

In any case, on the whole we can distinguish an area of true folding and another area of crystalline massifs, with predominantly fracture tectonics. The boundary between the two can be drawn with fair precision. It runs along the S margin of the Kalnik mountains, then along the S margins of the La Lepavina, Jagnjedovac, Mosti and Sedlarica structures and apparently strikes into the Drava plain at Vorovitica, SE of Sedlarica. The character of the E area ne around Vinkovci-Osijek is not, for the moment, entirely clear. To judge by the gravity pattern hitherto encountered only there, no true fold structures appear to occur, as a rule, in that region either. The only exception is the Fruska Gora itself, on the extreme E, which forms a clear, elongated and steeply upwarped ridge.

THE RELATION OF THE HITHERTO KNOWN OIL AND GAS FIELDS TO THE STRUCTURES

We shall still discuss, very briefly, the nature of the structures to which the hitherto known oil and gas fields in Croatia are linked.

IN THE FOLD AREA

The oilfields of Selnica and Pekelnica are connected with the certain favored points along the axis of the great buried ridge of Selnica-Peklenica which subsides towards the E. (Profile 2). The newly discovered oil-deposits of Peteshaza and Völgyifalu are located on broad terrace-like shallowings on the N flank of this buried ridge. (Profile 3).

The marked showings of oil on the Bdnja (Ludbreg) have accumulated where the N flank of the Ludbreg anticline falls off on one side, like a flexure, towards the Drava graben. (Profile 5).

The oil showings at Ribnjak and Veliki Poganec are connected with zones of dislocation along the axis of the emerging buried ridge of Subotica-Veliki Poganec. (Profile 9).

The gas showings in a shallow well at Mosti occurred near the axis of the structure at that place (Profile 13) as did the oil showings in the deep well at Sedlarica, which occurred at the high point of the dome on that structure. (Profile 15).

The small amounts of oil at Tuzla were discovered along the axes of the Eocene anticline, which is sharply folded at that place, and this applies particularly to the most important of these along the axis of the Jala-Pozarnica anticline.

IN THE MARGINAL AREAS OF THE GRABEN BETWEEN THE CRYSTALLINE MASSIFS

The gas-fields of Precec, Ivanic Klostar and Sumecani lie along the axis of the sill plunging NW from the Moslavina mountains, which at the same time also represents a terrace-like structure on the slope of the Moslavina mountains down to the Lonja-Sava depression. (Profiles 33 and 35.)

The oil seeps on Mikleuska and Srpsko Selisce outcrop at marginal fissures of the Moslavina mountains. (Profiles 37 and 39).

The gas fields of Sisak lie on the N flank of the gravity-spur of Prelescica (Profile 118). The gas fields of Struzec and Osekovo lie on the undistinctly demarcated terrace-like

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undulation on the NE end of the same spur. (Profiles 117 and 119.)

The oil and gas field of the Gojlo is located on an anticlinal undulation on the S precipice of the Moslavina mountains down to the Sava depression. (Profile 40.)

The gas-fields of Bujavica and Janjalipa lie on small domal uplifts along the Lipik-Bujavica-Janjalipa plunging sill (Profiles 52 and 55.)

The gas outcropping of Kozarica is connected with a terrace-like gravity-structure on the W piedmont of the Psunj mountains. (Profile 56).

The oil seeps at Paklenica are situated in the upper part of the gravity-cliff from the Kricke-Caglic to the Sava graben. (Profiles 59-60), and those of Lacindol on the fault, which shows up distinctly on the gravity-pattern as well (Profile 65). The geological buried ridge of Resetari lies in the same profile on a not very distinct gravity-terrace in the gravity-cliff leading to the Sava graben. The gas field there is linked to this buried ridge. Finally the oil seeps of Ostri Vrh near Staro Petrovo Selo are located on the marginal slope of the Pozega mountains down to the Sava graben. (Profile 68).

Only a few traces of gas are known in the E region. Vinkovci, where gases showed in a well drilled near the railroad station, is situated on a gravity saddle between the Jarmina and Markovac highs (Profiles 69 and 94). For the time being, the connection between the gas showings mentioned in the literature as occurring in the Danube loop at Erdut with the gravity pattern now found there has not been elucidated. (Profiles 84 and 86).

Indications for future exploration operations are furnished by these correlations between the gravity structures and the hitherto known occurrences of oil and gas.

In the folded region of the Danube the high axes of the anticlines and the upper areas of the domes merit priority of investigation, and then terrace-like shallowings and steep flexures and fractures leading from the highs down to the graben.

In the southern region the highest maxima mark the presence of crystalline massifs and thus are out of the question as drilling sites. In these areas the gravity-sills leading down from the massifs into the graben merit further study, especially when they bear dome-shaped local maxima. The marginal fractures and flexures of the massifs also deserve attention, and on these particularly the places where there are terrace-like interruptions of the gravity slope or anticlinal undulations like those at Gojlo.

On the whole the gravity meter surveys have resulted in far-reaching clarification of the structural geology of the entire region, in making more profound our understanding of the structures hitherto known, and in discovering numerous new structures possessing many characteristic features.

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